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REPORT OF COMMITTEE ON SERVICE PIPES.

[*Presented March 14, 1917.*]

TO THE NEW ENGLAND WATER WORKS ASSOCIATION:

Your Committee on Service Pipes begs to submit the following report:

The requisites for a good service pipe are, in order of their importance, (1) that it should not affect the water passing through it in such a manner as to make it injurious to the health of those using the water; (2) that it should not have a deleterious effect on the appearance, taste, or odor of the water even though not injurious to the health; (3) that it should have a sufficient capacity to give adequate service at all times; (4) that it should be strong and durable; (5) that it should be easily laid; (6) that it should be inexpensive.

To meet the first condition, that portion of the service pipe which comes in contact with the water should be of some material which is either not acted upon by the water standing in contact with it, or, if acted upon, produces no compounds which would affect the health of those using the water.

To meet the second condition, the material of which the inside of the service pipe is composed should not be acted upon by the water to produce rust or other substances which may come away with the water; it should not be composed of any material which will disintegrate; it must not be coated with any substance which will impart a taste or odor to the water.

These first two conditions should be considered absolutely essential in any system, for, as Mr. FitzGerald so well expresses it

in his discussion, " of what use is it to spend millions and millions on the quality of your water and yet allow services which affect that quality materially? "

To carry a sufficient quantity of water for good service, the pipe should be of suitable size, dependent, to some extent, on the available pressure, and should not become coated on the inside with rust or other material so as to diminish the flow to such an extent as to make the service unsatisfactory. The requirements of the water takers as to the rate of use of water are ever increasing, and these requirements should be met.

Strength and durability should be assured chiefly as a matter of economy. Where services are laid in streets having expensive paving, the digging up of a service pipe is a serious matter. The service should, therefore, be constructed of material that will stand the pressure which may be put upon it, and will not be corroded by the action of the water on the inside or the action of the atmosphere, or of substances which may be contained in the soil on the outside.

It is desirable to have a flexible pipe which may be bent around any obstructions which are likely to be encountered in the street and one which is not liable to break with any settlement which may take place.

The first cost of the service pipe is the last point which should be considered, for it is a very small item as compared with the cost of maintenance and the cost of renewals. In fact, it may be said that the service pipes cost the least to install of any portion of the water-works system and are capable of giving the greatest amount of trouble.

The service pipe which perfectly meets all of the above conditions has not been put on the market, and after many years' experience water-works men are not yet agreed as to the materials which most nearly meet them. The committee has, however, secured as much information as possible both from men of practical experience and those who have approached the subject from a scientific standpoint.

The committee began its investigations by sending to every water department in New England, and to the members of our Association outside of New England, a request for information in

regard to the materials and methods used in service-pipe construction, the troubles experienced, and other matters which appeared to the committee to be of interest in this connection.

Replies were received from over three hundred water departments, many of them giving complete and valuable information. There were, however, many things which the committee felt should be further explained, and at two meetings of the committee a number of superintendents who appeared to have had exceptional opportunities to obtain valuable experience along lines which it seemed important to investigate were invited to be present, and each of these men was in turn questioned in regard to the details of his practice and experience.

The committee has also had the benefit of the discussions which took place at two meetings of the Association prior to the appointment of the committee and the discussion of the preliminary report of the committee at the convention in September, 1916.

In considering the information contained in the replies received from the three hundred and more water departments, it should be borne in mind that the returns from New England include a large number of small places. The returns from outside of New England are chiefly confined to larger places.

Materials Used for Service Pipes.

The returns in regard to the material now used for new services may be summarized in table on page 326.

The use of plain wrought iron or steel for new services is becoming rare, while nearly one half of the places sending in reports now use galvanized wrought iron or steel exclusively. Galvanized pipes are used either exclusively or in part in 56 per cent. of the places; lead or lead-lined pipes in 31 per cent.; and cement-lined in 16 per cent. It is noticeable that the use of cement-lined pipe is largely confined to Massachusetts and New Hampshire, forty-six of the forty-eight places using it being in these two states.

Of the new water-works systems — those constructed within the past ten years — the following materials have been used for services:

Galvanized	24	Lead	2
Plain wrought iron	1	Cement lined	9

NUMBER OF WATER DEPARTMENTS USING SERVICE PIPES OF VARIOUS MATERIALS, AS REPORTED TO THE COMMITTEE.

Material.	Me.	N. H.	Vt.	Mass.	R. I.	Conn.	N. Y.	Other States.	Total.
Plain wrought iron or steel	1	...	1	6	1	3	1	...	13
Galvanized	15	19	4	54	6	26	6	15	145
Lead	...	1	1	15	4	5	6	16	48
Lead lined	1	3	...	7	....	...	...	2	13
Cement lined	...	5	...	32	...	...	...	...	37
Galvanized and lead	...	...	...	7	...	2	...	5	14
Galvanized and cement lined	...	...	...	4	...	...	...	...	4
Galvanized, lead and cement lined	...	...	...	2	...	...	...	...	2
Galvanized and lead lined	2	...	...	4	1	1	1	1	10
Iron and cement lined	...	1	...	1	...	...	...	...	2
Cement lined and lead lined	...	....	...	1	...	...	...	...	1
Cement lined and lead	...	...	...	....	1	1	...	...	2
Lead and lead lined	...	...	...	3	...	...	1	...	4
Lead and wrought iron	...	...	...	...	...	2	1	...	3
Miscellaneous	...	...	1	3	...	1	...	1	6
	19	29	7	139	13	41	16	40	304

CHANGES MADE IN MATERIAL USED.

Many towns continue to use for service pipes the material which has always been used since the works were installed, although in many cases much trouble has been experienced. There are, however, about one hundred places where changes are reported to have been made for various reasons. A study of these changes and the reasons given therefor is very interesting.

The table on following page gives the changes which have been made and materials used before and after the change.

The disfavor with which plain iron and steel are regarded is shown by the fact that 22 places have changed from these materials to some other, while only one place has reported as having taken up their use. Galvanized pipe, on the other hand, has lost only 17 while gaining 46. Lead and lead-lined pipes have gained 18 and 16 places respectively and lost 6 and 8. Changes to cement-lined pipes have occurred in 11 places, and changes

CHANGES.

From	To						
	Wrought Iron or Steel.	Enameled.	Galvanized.	Lead.	Lead Lined.	Cement Lined.	Totals.
Wrought iron or steel	...	...	11	4	3	4	22
Enameled iron	...	...	10	1	1	1	13
Galvanized	...	1	...	7	7	2	17
Lead	...	...	4	..	..	2	6
Lead lined	1	...	5	..	..	2	8
Cement lined	...	...	16	6	5	...	27
Totals	1	1	46	18	16	11	93

from cement-lined pipes to some other material have occurred in 27 places.

A comparison of the number of places now using the different materials with the number of places where this material has been abandoned shows that 63 per cent. of those formerly using plain iron or steel pipes have changed to some other material. Eight per cent. have changed from galvanized iron; 19 per cent. from lead or lead lined; and 42 per cent. from cement lined.

Of those places where changes have been made from galvanized pipe to some other material, 13 are supplied from surface sources, 1 with ground water, and 3 with filtered water. Of the places changing from lead or lead-lined pipe to some other material, 5 are supplied from surface sources, 13 from ground-water sources, and 4 from filtered sources. Of the places abandoning cement-lined pipes for other material, 18 are supplied with surface water, 7 with ground water, and 1 with filtered water.

The reasons reported for the changes are varied. The changes from plain and galvanized pipes are almost entirely on account of rust. The changes from lead pipes are largely on account of the possibility of lead poisoning, although in some cases it has been on account of expense or because of the bursting of the pipes under pressure. Lead-lined pipe has been abandoned on account of lead poisoning and trouble from bursting and because of the difficulty in making joints which will not corrode. Of 20 places reporting the abandonment of cement-lined pipes, 8 were on account of

trouble at the joints, 6 "for convenience," and 2 on account of expense.

A large proportion of the places where the works have been in operation for a sufficient time report trouble with service pipes no matter what the material used, except in the case of cement-lined pipes. With cement-lined pipes, 54 per cent. of the places reporting report little or no trouble. With galvanized pipe, 36 per cent. of the places report little or no trouble, and with lead pipe 10 per cent. so report.

The trouble with iron and steel pipes, both plain and galvanized, appears to be through the entire length of the pipe. The trouble with lead pipes appears largely at the corporation cock. The trouble with cement-lined pipes is very largely corrosion of the outside of the pipe just inside the cellar walls, with some trouble at the lead gooseneck.

Life of Service Pipes.

The data in regard to length of life of a service pipe and the period that elapses before it begins to give trouble are very unsatisfactory. The averages of the figures given in the returns are as follows:

	Years before Trouble Begins.	Life of Pipe (Years).
Plain iron or steel	12	16
Galvanized	15	20
Lead	10	35
Lead lined	10	23
Cement lined	14	28

Where Trouble Occurs.

The main sources of trouble from corrosion are largely inside the pipes, due to the action of the water. In certain soils, however, there is a rapid corrosion of the pipes on the outside, and, if the inside is protected, as in the case of cement-lined pipes, this is the main source of trouble. Pipes laid in salt marsh or in cinder-fill are certain to be acted upon rapidly. Pipes in clay are much more subject to corrosion on the outside than those in sand or gravel. One of the common places where trouble occurs is at

the corporation cock, or, where a gooseneck is used, at the junction of the gooseneck with the service pipe. Some of the troubles at the corporation cock are due to the tuberculation of the inside of the main pipe, which tends to cover the end of the corporation cock. This can be overcome in a large measure by inserting the corporation cock well beyond the inside of the main.

The following table gives the location of the principal troubles with different kinds of services as reported to the committee.

WHERE TROUBLE OCCURS.

	Plain Iron or Steel.	Galvanized.	Lead.	Lead Lined.	Cement Lined.
Throughout entire length...	10	49	17	8	2
Couplings and fittings.....	4	24	7	6	10
Cellar wall.....	3	8	5	6	13
Corporation or gooseneck...	7	20	14	6	14
Curb cock.....	3	8	6	2	4

THEORY OF CORROSION OF METALS BY WATER.

There are two main theories in regard to the corrosion of metals, —the carbonic acid theory and the electrolytic theory. According to the carbonic acid theory, which originated many years ago, iron is first dissolved by an acid, even weak acids such as carbonic acid being active. The ferrous salt formed by this corrosion is oxidized by the oxygen present in solution; the ferric hydroxide thus formed is precipitated, and CO_2 is liberated to act again on the iron. This is a cycle whereby a small amount of acid can effect the solution of a considerable amount of metal.

The electrolytic theory originated with Whitney, in 1903, and is based on fundamental principles of theoretical chemistry, the theory being that water and all substances in dilute solution are more or less completely dissociated into ions which convey positive and negative charges of electricity. Corrosion is caused, according to this theory, by one or more of the ions in solution being replaced by a metal. The hydrogen ions are most easily replaced, and hence are the active factor in corrosion. Anything in solution or any external force which tends to increase the concentra-

tion of hydrogen ions will increase the corrosive power of a water, while anything which tends to diminish the concentration of the hydrogen ions will decrease corrosion; for instance, metallic iron is attacked by the hydrogen ions, Fe going into solution as ferrous iron, and hydrogen changing from the ionic to the molecular or gaseous form.

According to this theory, iron should be attacked by the hydrogen ions in the purest water, and it probably is. Certain experiments, however, made at the Lawrence Experiment Station, in which iron pipes were tested with waters of varying character, seemed to show that pure distilled water, free from organic or mineral matters, had but slight corrosive properties unless free oxygen was present. Similar experiments with lead pipes gave like results. These results are in accord with those obtained elsewhere in studies of the factors influencing the corrosion of structural iron and steel, in which it has been proved many times that the presence of oxygen is an important factor.

The corrosion of metals by stray electric currents is well known, and these stray electric currents are of great importance as affecting the strength and life of water mains and other metal structures by corrosion. Small currents of electricity between metals of different potential are also important factors in the corrosion problem, and theoretical and electrical chemists have found by experiment that the metallic elements vary widely in electrical potential.

It has been shown that electric currents caused by unequal heating of different parts of a steam boiler are responsible at times for the destruction of boiler tubes. Impurities in a metal also cause local electrolytic action. The purest iron is thrown into nodes of positive and negative potential when immersed in water, and a scratch on the surface of polished metal may make it of different potential from the remainder of the surface and become the starting point of corrosive action. Iron, lead, or tin pipes, portions of which are wet and other portions dry, are apparently thrown into zones of varying potential, and corrosion occurs more or less actively at the junction of the wet and dry areas.

The factors entering into corrosion are too many to be enumerated here, but a review of them and a collection of references to

articles in regard to corrosion are given in an article published in the forty-second annual report of the Massachusetts State Board of Health, entitled, "Studies of the Relative Corrosion of Metal Pipes by Waters."

This committee is chiefly concerned with the practical corrosion of service pipes in actual use and the character of waters which will most actively corrode metallic pipes.

It was apparently shown by the State Board of Health of Massachusetts, in an investigation during 1898–1900 inclusive, that the cause of the taking of lead from the service pipes of certain towns and cities of the state (that is, the corrosion of these pipes) was the presence of a considerable volume of free carbonic acid in the ground waters supplied to these cities and towns. Corrosion of lead pipes was not serious in towns with surface-water supplies. It was shown during these investigations that soft water free, or comparatively so, from mineral matter, when containing some dissolved oxygen, attacked lead, and that the presence of certain other bodies as free ammonia, nitrates, etc., apparently caused the water to have some solvent action, yet that in actual practice with the conditions prevailing in the service pipes of a distribution system, a potable water in Massachusetts with a dangerous lead-dissolving action always contained considerable free carbonic acid.

It was also shown that the greater the hardness of a water compared with the free carbonic acid present, the less was the corrosive power of such water. This work was completed before Whitney published his article upon the electrolytic theory of corrosion, but the results in the light of further study seem to uphold the carbonic acid theory, although probably not at variance with the electrolytic theory.

Most New England waters have generally very little action on tin and copper, hence pipes of these metals are but slightly corroded by water unless electrolytic action occurs, owing to the use of connecting metals with different potential. Certain New England waters have a very decided action on iron and steel, and the softer the water the more likely is this action to occur. The corrosion of iron and steel pipes has been long noted, and extensive studies of the subject have been made in recent years, owing

to the occurrence in certain localities of what is known as the " red water plague." This has been studied from the consumer's point of view, and largely in regard to the corrosion of piping within dwellings. Articles in engineering papers since about 1909 have called attention to the occurrence of rusty or red water in many places, and have stated that such troubles were common and serious in the case of some ground waters and certain soft waters of the east and south which had been purified by mechanical filtration. Other writers have called attention to the fact that swampy waters also cause this trouble. An extensive investigation was made in regard to the Springfield, Mass., water in 1910. In this investigation the greater part of the trouble was found to be in places where the plumbing had been recently installed and where a poor quality of galvanized steel was used for pipes and hot-water boilers, and the trouble was stated to be due to electrolytic action either in the imperfectly galvanized materials or at the junction of unlike metals. This experience was with steel pipes, but it has been stated that in the municipal bath houses of New York City hot-water pipes have to be replaced frequently, and that there is apparently little difference in the rate of corrosion of galvanized iron and galvanized steel pipes. This has been noted at other places. In modern methods of manufacture, the line of demarcation between iron and steel is not clear, and it is probable that in some instances steel pipe is used when iron is intended for use, and vice versa. The fact that waters purified by the use of sulphate of alumina might be more corrosive in their action upon metals after than before purification, was first mentioned in the reports upon the purification of the Ohio River water at Louisville in 1899, and the suggestion was made that the corrosive action might be checked by the use of lime. The increased corrosive action in such cases is due to increased carbonic acid and the fact that a purer water results; that is, one containing less organic matter. A sand-filtered soft water is also more corrosive than the same water before filtration.

Corrosion and the Public Health.

The literature of corrosion in connection with public health is fairly extensive, and extends farther back than the beginning of

the Christian era. Hippocrates recognized the danger of lead poisoning in connection with water supplies, and the fact that water conveyed through lead pipes or held in lead cisterns sometimes became poisonous was commented upon by medical writers of the middle ages.

Twenty years ago there were many cases of lead poisoning in certain cities and towns of Massachusetts having ground water supplies and lead service pipes. From investigations in regard to these cases, and determinations of the amount of lead in the water used, it was decided that it would be safe to assume that the habitual use of water containing lead in an amount equal to, or greater than, 0.04 parts in 100 000 might cause lead poisoning. It is only fair for this committee to state, however, that lead pipe is in common use in many municipalities both as service-piping and in household plumbing, and apparently without ill effects to the consumers of the water passing through these pipes. The action of these Massachusetts waters upon lead was ascribed, as previously stated in this report, to the fact that they were fairly soft and contained considerable carbonic acid.

There is little to be found in regard to the action of zinc, tin, and copper in water supplies as affecting public health, and it is probable that few waters take enough of these metals in solution to have a toxic effect upon their consumers. There are only one or two instances that can be quoted in regard to disturbances of health caused by zinc, and these are not well authenticated. It is improbable that any amount of iron in water has ever affected the health of consumers except perhaps beneficially.

Plain Wrought Iron and Steel.

The committee believes that there are very few cases where the use of either wrought iron or steel pipes without some protective coating for services is justifiable. Such pipes are certain to become filled with rust, and the expense of cleaning or renewing them will much more than offset the extra first cost of coated pipes. Covering the metal with some protective paint seems to increase its life but slightly.

In the compilation of the returns, wrought iron and steel have been grouped together, as it is evident that the words are used

interchangeably in many cases. Of those making returns, however, very few have said that steel pipes were now used, and a considerable number have called attention to the fact that only genuine wrought iron was used. Others have stated strongly their belief in the superiority of wrought iron over steel, deeming it of sufficient importance to call for special remark.

The relative merit of steel and wrought iron has been a matter of controversy ever since steel pipe has been on the market. The steel pipe has the advantage of greater strength and lower cost, but the advocates of wrought iron claim that the steel corrodes more rapidly, has a much shorter life, and is more difficult to work. The advocates of steel contend that the life of steel is as long as, if not longer than, that of wrought iron. Both sides produce evidence to support their claims, much of which appears to be trustworthy. The claims of both sides, also, are supported by competent experts.

The behavior of pipes under different conditions is so different that the greatest care must be exercised in drawing conclusions. The action of different waters on both steel and wrought iron is quite different, so that the results obtained in different places cannot be compared. The action of the water on a pipe depends to a considerable extent on the quantity passing through it, and a pipe which contains dead water much of the time will corrode much less rapidly than one which has a continuous flow. For these reasons, conclusions based on the appearance of occasional samples are worthless, and even two pipes side by side may not be comparable, owing to a difference in the flow through the pipe. The character of the metal should also be taken into consideration, as there is wrought-iron pipe, for example, which is of inferior quality and will not resist corrosion as well as high-grade wrought iron, and there is undoubtedly much steel pipe sold as wrought iron.

In regard to the working of the steel, there seems to be no doubt that the same tools used for wrought-iron pipes cannot be satisfactorily used for steel pipes, but that with suitable tools the steel pipes can be worked without any difficulty.

The experience of water-works superintendents as indicated by the returns and as shown by previous discussions in the meetings

of the Association is decidedly unfavorable to steel pipe, and while, undoubtedly, many of those who argue in favor of wrought-iron pipes may be unfamiliar with anything else, and believe in it because they were taught to believe in it, there is certainly a large number of reliable men who have had an extended experience with both materials who are firmly convinced that wrought iron is much superior to steel, and it would seem that there must be some good reason for this belief.

The feeling against steel pipes appears to be chiefly confined to New England, for it is undoubtedly a fact that a majority of the service pipes used in other sections of the country are of steel, and it is apparent that no more trouble is experienced from the use of steel in these places than is experienced from the use of wrought iron in this vicinity.

Galvanized Pipe.

The action of water on zinc is comparatively slight, and if the pipe — whether of steel or wrought iron — is completely covered with zinc the life of the service will be very materially lengthened. The chief trouble with galvanized pipe is in the joints, where the water gets directly at the iron, and in the imperfect covering of the iron or steel.

As pipes are manufactured, there is a large quantity of scale left on the pipe, especially on the inside. In the galvanizing process this scale is simply covered with zinc. When the scale becomes loose, as it invariably will, the metal of the pipes is, in spots, exposed directly to the action of the water and corrosion begins, which tends to loosen still further the scale, and soon the pipe is little better than an uncoated pipe. The wrought-iron pipe advocates claim that the greater roughness of the wrought iron insures a greater quantity of zinc, but the extra zinc in this case is obviously not so distributed as to be of any material value.

If the pipe could be freed from scale before galvanizing, leaving a comparatively smooth surface, the effects of galvanizing would be much greater, as there would be little opportunity for the direct action of the water on the iron. The National Tube Company has now perfected a method of removing scale from the

pipes much more effectively than has heretofore been practicable, which would seem to be of enormous advantage both in decreasing the friction in the pipe and especially in making it possible to obtain a much more durable coating of zinc when galvanized. This process, which is applicable both to wrought-iron and steel pipes, is likely to result in the production of very much better galvanized pipe.

Galvanized pipe appears to be the cheapest practicable material for services where the class of street surfacing is not such as to make the renewal of the services a matter of great expense. Services of this material will give trouble, especially with waters which attack metals readily, but there is no possibility of danger to health in their use.

Whether steel pipe is as durable when galvanized as is wrought iron, is a matter which is open to discussion. If the galvanizing is perfect, it would make little difference whether the metal under the zinc resisted corrosion more or less. With the process for removing scale above referred to, it would seem that a long step had been made towards getting a perfect galvanized pipe.

Lead Pipe.

Lead is in many respects the most satisfactory material to use for service pipes. Its pliability and its comparative freedom from corrosive action make it almost ideal from a mechanical standpoint. The cost of lead pipe of sufficient thickness to safely withstand the pressure is more than the cost of many other materials used for services, but in a paved street the greater duration of life probably more than compensates for the extra cost, and in places where the streets are occupied by other pipes and conduits the ease of getting over and under these obstructions with a flexible pipe is a great advantage.

The most serious objection to the use of lead pipe for services is the possibility that the water may dissolve enough lead from the pipe to cause lead poisoning. It is certain that many cases of lead poisoning have been caused by the use of lead services, and water companies have had to pay considerable amounts in damages where they have supplied water through lead pipes and lead poisoning has resulted. On the other hand, lead has always been

used for services in most of the large places without any known unfavorable effects.

The reason why trouble has resulted in some places and not in others is found in the different character of water supplied in these places. With soft water which contains considerable carbonic acid, the action of water on the lead is very rapid. Waters obtained from reservoirs are not likely to have carbonic acid, and instead of a corrosive action the water tends to form a coating of an insoluble lead compound on the inside of the pipe. With such waters there is no great danger in the use of lead except, possibly, when the pipe is new. The danger in such cases lies in the possibility that at some future time the character of the water will change either by the introduction of new sources of supply or by filtration of the old supply.

It seems to be practically impossible to determine definitely in advance what the effect of any water on lead pipe will be, as the laboratory results fail in many cases to show the action which will occur in actual practice. Tests of service pipes in use for a considerable period are the only safe guides.

The health authorities of several of the New England states advise most strongly against the use of lead for service pipes, even where the character of the water now in use is such as to indicate that there would probably be no injurious effects.

Lead-Lined Pipe.

Lead-lined pipe as manufactured several years ago gave much trouble from the separation of the lead lining from the iron, leaving the metal exposed to the water. The pipe as manufactured to-day, however, appears to be durable and prevents the corrosion of the iron or steel very effectively. It would seem that the life of such pipe would be limited only by the corrosion of the outside of the pipe.

The expense of the lead-lined pipe is much less than that of lead pipe, and it has the advantage of greatly increased strength. On the other hand, it does not have the advantage of flexibility.

All of the dangers from the dissolving of lead which have been enumerated in the case of lead pipes apply equally to lead-lined pipes.

Cement-Lined Pipes.

Cement-lined pipes, if properly constructed, make ideal service pipes as far as the interior of the pipe is concerned. The cement is not acted upon by water and the interior of the pipe will remain smooth for an indefinite time. There are many places where cement-lined pipes have been in use for many years without any trouble, and there are many other where they have given so much trouble that their use has been discontinued. As far as the committee has been able to learn, the troubles with cement-lined pipes have been almost entirely from imperfect work or from the use of fittings which did not prevent the water from getting to the metal.

For lining pipes, Rosendale cement is most commonly used, although in some places Portland cement has given good results, and a mixture of the two cements has also been used.

The methods of making joints which will not cause trouble are described in the discussion. The simplest method appears to be to line the coupling with the pipe and then dig out the cement from the coupling to receive the other pipe. The placing of a nipple temporarily on the end of the pipe while it is being lined appears also to have been successful. In some places lead-lined couplings have been used or brass ferrules have been inserted. In general, it may be said that the best method is that which most nearly preserves a smooth and unbroken lining of cement.

Cement-lined pipe can be bent sufficiently to pass ordinary obstructions in the street, but it should not be used until the lining has been on for a sufficient time to allow the cement to become well set,— a period of several weeks.

Several of the smaller plants have abandoned the use of cement-lined pipes on account of the trouble and expense of lining them. Within the past few years, cement-lined pipes and fittings have been put on the market, and it is claimed that they can be shipped without serious injury. If this claim is well founded, and the evidence indicates that it is, the use of this material will be much more practicable in the smaller places.

Trouble with cement-lined services occurs most frequently from corrosion on the outside of the pipe, and especially where the pipe enters the cellar. In many cases the action on the outside

of the pipe is quite rapid, and samples have been submitted to the committee where the iron has been completely eaten through and nothing but the cement remains to hold the water. This rapid corrosion is probably due to the dampness inside the cellar wall. Various methods have been suggested for remedying this. A short piece of the pipe where it passes through the cellar wall may be encased in cement, or a short section of brass pipe may be used from the outside of the cellar wall to the stop and waste. Another suggestion is that a coupling be placed just outside the wall, so that the corroded piece may be readily removed and replaced. Painting the outside of the pipe is resorted to in some places with good results.

The use of galvanized pipes for lining with cement undoubtedly gives the pipe a much longer life, as the outside is in this way protected from corrosion to a large extent.

Pipes of Other Materials.

Other materials have been used to some extent in the construction of service pipes. The enamel pipe which was common some years ago has practically gone out of use, although there is one town in Massachusetts which has recently adopted it and has installed a considerable number of services of this material within the past two or three years. The claim is made in this case that the enamel is of considerably better quality than that formerly used, as it has been given severe tests and passed through them satisfactorily. The test of time, however, has yet not been applied.

Tin has been used to some extent, and is an ideal material for service pipe work, but the great expense of the tin makes it practically out of the question.

Brass is used in a few cases, especially where the corrosive action is likely to be great, but the expense of brass pipe is too great to make it practical at the present time.

Size of Service.

The standard size for services is ordinarily $\frac{3}{4}$ in., but in several cases this size has been increased to 1 in. or even to $1\frac{1}{4}$ in. for the purpose, chiefly, of lengthening the life of the service. Where

plain or galvanized steel or wrought-iron pipes are used, the pipes soon begin to fill up with rust, but the service which they render is fairly satisfactory until the pipes become nearly choked, when they must be cleaned. A 1-in. pipe has about twice the area of $\frac{3}{4}$-in. pipe and will probably last at least twice as long before it will require cleaning. Where meters are not used, there is some objection to the use of large service pipes, as the waste of water from leaks and from carelessness and the use of water through garden hose is considerably greater with the larger service. Where meters are used, this objection does not apply, and it seems to the committee that much trouble and expense might be saved, where pipes are used which are liable to corrode, if the services should be made of larger size. Furthermore, a $\frac{3}{4}$-in. service pipe of any considerable length will not, in many cases, give a satisfactory flow of water to meet the modern requirements.

The extent to which larger service pipes are used is shown in the following table, which gives the standard size reported by those making returns.

Standard Size of Service. (Inches.)	Number of Places.
$\frac{1}{2}$	16*
$\frac{5}{8}$	33
$\frac{3}{4}$	198
1	51
$1\frac{1}{4}$	5
$1\frac{1}{2}$	2

Goosenecks versus Rigid Connections.

Rigid connections with the main and the omission of the goosenecks are used in a large number of places, and in some places such connections are used exclusively. The advantages of the rigid connections are obvious. They make a considerable saving in the first cost, and they are much more readily cleaned. On the other hand, the gooseneck permits the dropping of the service below the main and away from frost, and it is possible to make the service take any direction from the main.

The cost of using goosenecks and the troubles which result from them have been considerably reduced by the use of lead

flange connections instead of wiped joints. Judging from the testimony of those who use them, the lead flange connections have given much better satisfaction than the wiped joints and can be made by any workman.

Where rigid connections are used, it is necessary to have the pipes rest on a firm foundation, as any settlement in the service pipe near the main may cause the service to break. The digging up of the street near the main may also cause trouble to rigid connections. The fact that 83 towns report the use of rigid connections to a greater or less extent, and that 56 of these report no trouble, and many others "little trouble" or "some trouble," would indicate that the use of rigid connections is thoroughly practicable in many places. In the larger cities, where the streets are occupied by many pipes, conduits, and other obstructions, and are frequently dug up, it would not seem wise to attempt to use the rigid connections.

Cleaning Service Pipes.

During the past few years great advances have been made in the methods of cleaning service pipes, and it is now possible to save large sums which have heretofore been paid for digging up the services and for renewals. The committee has not discussed the merits of the different types of cleaners, but all of them seem to have some merit. The most satisfactory in many cases, and especially with lead pipes or when goosenecks are used, is the force pump and wad of paper, which permits the cleaning of the gooseneck and corporation cock as well as the straight pipe.*

Method of Paying for Services.

Custom varies as to the method of charging for services, but in New England the general custom is for the department to pay for the service from the main to the curb cock or to the property line, the remainder being paid for by the owner. Outside of New England the custom appears to be quite different, and in the majority of places making returns the customer is obliged to pay practically all of the cost of the service from the main to the house.

*Journal N. E. W. W. A., Vol. XXVIII, p. 70.

The following table gives the proportion of the cost of the services paid for by the water departments in New England and in the states outside of New England.

PORTION OF SERVICE PAID FOR BY WATER DEPARTMENT.

	Number of Places.		
	New England.	Other States.	Total.
None	41	38	79
To curb or property line	174	10	184
Corporation	8	4	12
Corporation and curb cock	3	...	3
Miscellaneous	15	2	17

PORTION OF SERVICE LAID BY WATER DEPARTMENT.

The almost universal opinion among superintendents, especially in New England, is that the water department should lay and maintain all the services from the main to the stop and waste in the cellar, whatever portion of the expense may be borne by the department. The superintendents in many places where this is not now done express themselves very strongly in favor of it, as the department can then prevent much of the leakage from defective services and prevent much of the trouble from freezing.

The following table gives statistics in regard to the portion of the service which is laid by the department and the portion laid by the owners.

PORTION OF SERVICE LAID BY WATER DEPARTMENT.

	Number of Places.		
	New England.	Other States.	Total.
None	27	17	44
To curb or property line	94	24	118
To cellar	117	6	123
Corporation	...	6	6
Miscellaneous	2	...	2

Conclusions.

Service connections may and frequently do give more trouble than any other part of a water-works system, causing the deterioration of an otherwise good water and constituting an unduly large proportion of the maintenance expense. The preservation of the purity of the water is obviously the most important requisite, and only those materials should be used which will not impair in any way the quality of the water.

The cost of the installation of services is so small in comparison with the total cost of the system, and the expenses for repairs and renewals are so large, that only the most durable materials should be used.

There are very few, if any, places where it is advisable to use uncoated wrought iron or steel in service-pipe construction. The metal will corrode more or less rapidly, according to the character of the water, clogging the pipes, giving trouble in the houses from rusty water, and eventually requiring renewal of the service.

The use of galvanized pipe decreases very materially, in most cases, the troubles experienced from the use of plain wrought iron or steel. With some waters, galvanized pipes will give little or no trouble and will last many years. With other waters, the zinc will be rapidly dissolved and the pipe will then become no better than an uncoated pipe. Better methods of galvanizing will undoubtedly produce better results in service, and the process now being adopted of removing scale from the inside of the pipe before galvanizing gives promise of good results.

Lead pipe is mechanically an almost ideal pipe for services, on account of its flexibility and the ease of laying in streets where there are obstructions. With waters which do not attack the lead, this material is almost indestructible unless subjected to the action of electrolysis. The lead does not corrode and the pipe remains smooth and clean. The serious objection to the use of this material is the possibility that it may affect the health of those using the water. It is certain that lead services have been in use in many places for a great number of years without any known serious results, and it is equally certain that in other places where they have been used, very serious results have ensued, involving loss of life and the payment of heavy damages therefor.

Many waters act on lead to produce insoluble carbonates on the inner surface of the pipes.

The action of the water on the lead depends on the character of the water and the addition of a new source of supply, or the filtration of the water may produce conditions entirely different from those which now obtain. One case of this kind is referred to in the discussion.

It seems to be practically impossible to determine in advance by laboratory tests whether or not the use of lead will be safe. The only sure test is one of several years' duration in actual service.

In view of the serious consequences which may result from the use of lead, the committee believes that in new works, at least, it is advisable to use some other material for services. In those places where lead has always been used and it is known that the water does not dissolve the lead, its use may be continued until something occurs to change the character of the water, when the effect of this change should be carefully watched.

Lead-lined iron or steel pipe, like lead pipe, will retain a smooth and clean interior, and, as far as the action of the water is concerned, will last for a long period. It has the merit of being stronger and cheaper than lead pipe. The outside of the pipe is subjected to the action of the soil and of the atmosphere, and, unless protected in some way, will rust out as in the case of other material.

Lead-lined pipe carries with it all the possibilities of danger to health that attend the use of lead pipe.

Cement-lined pipes are the most satisfactory, so far as the action of the water is concerned, of any which are now used for services. The difficulties which arise from the use of this material are solely mechanical. Water has no appreciable action on cement, and the cement lining, if properly constructed, will last for an indefinite time.

The troubles which have occurred appear to be due entirely to imperfect work either in lining the pipes or in making the joints. Unless the outside of the pipe is protected, corrosion will take place, the same as in the case of plain and lead-lined pipe.

The waters which will attack metals most actively are, in general, the soft, clear waters. Ground waters are more apt to attack metals than surface waters, and hot water has more effect than cold. Filtered waters are much more active than unfiltered waters.

Waters which attack one metal will, in general, attack another, and changing from iron pipe which corrodes badly to lead pipe is likely to produce a dangerous condition. The reason why galvanized pipe is more satisfactory than plain pipe is that the action of the water on the zinc is somewhat slower, and the products of the corrosion of zinc are soluble and innocuous, but the zinc will be eaten through in time and the iron will then be open to attack. The more water which passes through the service, the more rapid will be the action on the metal. Stagnant water will have little effect.

Corrosion of the outside of the pipes is a serious matter, especially in the case of lined pipes, where it generally determines the useful life of the pipe. Outside corrosion is especially serious in clayey soils, in salt-water marshes, ashes or cinders, and near stables. The greatest troubles from this cause, however, occur just inside the cellar wall.

For corrosion in the soil, the best remedy is to use a coated pipe, and in many places where cement-lined pipes are used, the pipes are galvanized. Where the pipe passes through the cellar wall, a pipe encased in cement may be installed, or a short length of brass pipe may be used. In some places a coupling is placed just outside the wall, so that a short section can be readily removed and replaced.

With regard to the relative merits of wrought iron and steel, the great majority of users of these pipes testify strongly in favor of the former. It is undoubtedly a fact that the strong preference for wrought iron is confined chiefly to New England, and that steel is used very generally in other sections of the country.

The experience of superintendents indicates that the steel corrodes more rapidly than wrought iron, and some claim that it is much more difficult to work, although it appears from the testimony of many others that there is no difficulty in cutting and threading the steel pipes if proper tools are used, the tools ordinarily used on wrought iron not being suited to use on steel.

The concensus of opinion among water-works men in New England is that the water department should lay and maintain all services from the main to the stop and waste in the cellar.

Custom varies as to the method of paying for services, but in

New England the general custom is for the department to pay for the services from the main to the curb-cock or the property line. Outside of New England, in the majority of cases the customer pays practically all of the cost of the service.

Rigid connections with the mains appear to possess many advantages over the use of a gooseneck, and the experience in many places shows that there is no trouble to be expected where the soil is suitable and there is not much digging up of the streets for sewers and conduits.

Lead flange connections appear to be superior to wiped joints.

The committee believes that in many cases the standard size for services can be made one inch to the advantage both of the consumer and the department. The requirements in the modern house are much greater than in the past, and some plumbing fixtures require a larger flow than can be obtained through a $\frac{3}{4}$-in. pipe of the average length and with ordinary pressure. The use of meters will control the waste which otherwise might be greater with the larger service. In a pipe which tends to fill up with rust, the larger service will last much longer before cleaning is necessary than the smaller pipe.

Respectfully submitted,

WILLIAM S. JOHNSON,
H. W. CLARK,
GEORGE A. STACY,
WILLIAM F. SULLIVAN,
ALFRED E. MARTIN,
Committee.

DISCUSSION.*

MR. R. C. P. COGGESHALL.† In June, 1884, Walter H. Richards, of New London, Conn., presented to this Association a remarkably able paper entitled, "Service Pipes, Material, Size, etc." This was followed by a lively discussion. That was thirty years ago, and yet that paper reads as well to-day as when written. Indeed, the whole discussion would pass well for a product of a meeting

* On the preliminary draft of the committee's report, submitted September 14, 1916.
† Superintendent Water Works, New Bedford, Mass.

held to-day. It is interesting to look over the replies to the questions submitted to the members at that time. The questions were as follows:

1. *Lead Pipe.* Please state sizes used by you, giving weight per foot and head in pounds pressure for each size used, and also whether you have had any bad results from the use of this pipe.
2. *Wrought-Iron Pipe.* Please state the kind used and your experience with same.
3. Please state the kind you are now using and your reason therefor.
4. Please state the kind of service pipe you would prefer to use, and your reasons therefor.
5. Please give information acquired by your experience in the use of service pipe which would be of interest to the Association.

The tabulations which may be found in the Proceedings of 1884 show forty-one replies to these questions. Of this number, the pipe in actual use in the various departments represented was,

Lead.	Galvanized Iron.	Enameled.	Cement Lined.	Tarred Wrought Iron.
10	9	6	9	7

The preferences of the superintendents submitting replies were,

Lead.	Galvanized Iron.	Enameled.	Cement-Lined Wrought Iron.	Tarred Wrought Iron.	Brass.
20	5	3	5	7	1

The enameled wrought-iron pipes of those days have long since disappeared, proving to be worthless, and a most excellent pipe known as lead-lined wrought-iron has since been developed, and appears to be giving satisfaction to those using it.

At the time stated, the speaker gave his preference for lead pipe. During the additional thirty years which have followed he has seen no reason to revise that opinion. In reply to those who seem to fear trouble due to lead poisoning, would say that every locality should determine for itself whether or not the quality of water is proper to permit the use of lead pipe. We all know that it cannot be safely used in all waters. In all of my long years of experience I never knew a case of illness which could be attributed to the use of lead pipe, in supplying our customers through the fifteen thousand services now in commission.

MR. E. C. BROOKS.* I think that most of you will agree that lead is an ideal metal for a supply pipe. It certainly has a great many things to recommend it, — in that it can be easily connected, and from the nature of the metal adjusts itself to the expansion and contraction due to the heating and cooling of the water in the ground. In these days, when streets are so well made and paved, and granolithic sidewalks laid, of course it becomes necessary to so put in service pipes that they shall require attention or repair as seldom as possible. Its being able to fulfill this requirement adds, of course, very materially to the worth of the lead pipe for services. Although lead pipe may not tend to corrode or fill up, as some of the other services do, still we know that composition fittings do fill up and that it is necessary if possible to clean them out.

I believe that a service pipe connected on the horizontal diameter of the pipe, without any crooks or bends or anything of that kind, answers the purpose better than those put in with any of the so-called goosenecks. Certainly if it is possible to clean anything it can be cleaned as a straight pipe, whereas if you use a gooseneck you have got to take the pipe up anyway. I have had some experience in cleaning services, and must say that some of the work was very gratifying indeed.

We know that there are sections where lead pipe is looked upon with horror as a water carrier, and a great many persons have very strong feelings in regard to having anything in the way of drinking water pass through lead. Of course where that feeling prevails we are obliged to resort to either galvanized iron or some of the lined supply pipes for service lines. And they of course cannot be laid much cheaper, if any cheaper, than lead — that is, for ordinary pressures. But I think that all who have had much experience with iron services must have had trouble due to the expansion and contraction of the service and the breaking off of the curb cocks from that effect. It has occurred to me that possibly a cheap expansion joint might be put in adjacent to the curb cock that would overcome the difficulty and avoid that trouble.

The galvanized-iron or lined supply pipe can certainly be

* Melrose, Mass.

cleaned very readily and very thoroughly. I have thought that probably in the future we are going to have a flexible cleaner, after the manner of the flexible connections used in machine shops in drilling, and by the dentists for driving their drills and burrs. There is electricity in almost every house that you come to now, and a small motor connected to a flexible shaft can certainly very readily clean out a supply, and do it thoroughly.

There is one thing that bothers us in these days, and that is the freedom with which the public-service corporations are allowed to put their conduits in the streets. In street after street the water pipes are blanketed by the public-service corporations' conduits, so that in putting in a supply you have got to offset under them or over them, and resort to all sorts of means to get round them. It seems as though the municipality ought to have the right of way in the street, and that a zone should be reserved for their pipes, free from obstruction by conduits or other pipes.

MR. W. H. RICHARDS.* The first requisite of a service pipe is that it shall be sanitary; that is, that it shall not affect the water passing through it in a manner deleterious to health. All other qualifications are subordinate to its permanence or lasting qualities, and this is particularly the case in these days of improved roads and permanent pavements.

A moment's thought will show any practical man that true economy demands that any structure built underground should be of the most permanent and lasting character.

A large portion of the cost of a service pipe is composed of the labor cost, which, when the pipe is relaid, has to be duplicated, so that, even if it has to be repeated only once in twenty-five years, it is done at a distinct loss.

I think that it may be said, without danger of refutation, that, after a trial of a thousand years or more, lead has proven the most permanent service pipe, and next to that brass, which has been universally used for the fittings.

In the few cases where it is distinctly proven that the water is of such quality that it will attack lead, brass might be substituted; but it is somewhat doubtful if water which would attack lead would not also corrode brass.

* Engineer, New London, Conn.

But, as more or less brass and lead is used on all fixtures throughout any work, the question is one of degree, and this raises another question, — Is such a water fit to be taken into the human stomach?

Latterly it has become the fashion to select a water supply, the water of which requires dosing with bleaching powder, and the stomach that can stand that ought not to revolt at a little lead.

In fact, I think it could be shown that, where a water supply is of such quality as to attack lead service pipe to a harmful extent, it should be abandoned for a new supply.

Regarding the purely economic aspects of this discussion, I may say that the first cost of service pipe, per foot, in the city of New London, has not materially changed in forty years, although in that time we have changed from cement-lined to lead.

In conclusion, I would say further, that, with a few typographical corrections, the paper by the writer, which was published in the proceedings of 1884, still expresses his opinions.

Mr. F. F. Forbes.* For forty years we have used in Brookline a wrought-iron pipe lined with cement, and in that whole forty years I have never had a failure within the straight pipe; I have never taken out a pipe that has shown any signs of rusting through of the iron or an accumulation of anything on the cement; the bore has always been clear.

We have had some trouble where the iron pipe connects with the shut-off in the sidewalk. In the forty years of my experience there have been twenty-five or thirty cases where the pipe has broken down quite a bit at the curb cock; but never in the lining of the pipe, even where the pipe is joined together.

We always use a gooseneck at the main — a piece of bent pipe. One reason for that is that in Brookline the streets are dug up constantly. They dig under our service pipes, and we don't know about it until the thing is all done; but in this way we save a great many leaks. I have had those goosenecks almost straightened out, and a great many of them have been broken off. But I would rather a gooseneck would break than some other part of the pipe.

I find that you can bend a cement-lined pipe and it does not

* Superintendent Water Works, Brookline, Mass.

hurt it a bit; it does not crack. I have tried it time and time again. You can make an easy bend ten feet in diameter, and the cement does not crack a bit.

We used to use the F. O. Norton cement, but we cannot get that now. We use the best grade of American cement.

I might state briefly how we line the pipe with cement. After our pipe is delivered, we take off the couplings and reverse them and put them on the other end of the pipe. Although we buy plugged reamed pipe we run the reamer through all the pipe again, to be sure that there are no bunches left. We sift our cement through a very fine sieve because, in the best of cement, there are apt to be little lumps. After a pipe has been lined for about a week, we mix up a thin grout in a waterpot and run it through all the pipe, — lay it down on the floor and take it up and run through a rubber cone. We use the same cement for grout as is used in lining the pipe. By grouting the pipe in this way we cover up any little porous places and get a very smooth surface. We now dig the couplings out, which are all made on solid. We use a gage and dig them out so that the pipe will make up the last thread and then butt on the cement. Then we make up to the last thread — not too far to injure the lining.

We use Byers' galvanized wrought-iron pipe. We have some salt marsh and a good deal of filling in Brookline, and we find that plain wrought iron corrodes in a very short time.

In lining the pipe I run two cones through once, one cone behind the other, and then run them through a second time. The second time I revolve the pipe as the cone goes through, to keep the cone from going to the bottom side of the pipe.

We have six men that line pipe, and they can line between four and five thousand feet of pipe a day.

For 1-in. service pipe we use a 16-ft. length, but on a 2-in. we use a longer length. In using this length the cement will not run in back of the cone.

Mr. E. D. Eldredge.* One principal feature of the Onset water is its extreme softness. Sometimes the report of the State Board of Health analysis has shown zero on the scale. For that reason we have trouble from the color of the water, derived from

* Superintendent Water Company, Onset, Mass.

the cast-iron mains. That is the worst trouble we have. About every week we have to devote a whole day to blowing off in different sections of the town, and we have to do it systematically, so as to renew the whole contents of the pipe.

We used galvanized services for some years, but found that after a while the galvanizing came off and the pipe seemed to gradually close up and rust at the joints and the couplings, and tubercles formed; so we introduced cement-lined services, about 1897, and since then we have had no reason to regret it. Every case has been satisfactory. We have had no services stop up, although I have no doubt that at places the flow is decreasing.

With galvanized services the amount of formation depends very decidedly on the amount of water passing through. In some cases where a pipe is carrying water the year around, particularly a small constant flow, the pipe seems to collect rust, and in time it almost closes up. On the other hand, services that are in houses that are occupied but a short time — two or three months in the summer — seem tc be in good condition yet. So it depends largely upon having a constant supply of new water. If the old water remains in the pipe, it doesn't seem to injure the pipe at all.

The cement lining process is done with some care, and always by the same men. We have three men that operate on it, and every piece of pipe is carefully inspected from both ends. In order to insure the success of the inspection as well as the convenience in handling the pipe, we cut every length in two, cut a new thread, reverse the coupling, make sure that both threads are good, screw the couplings on tight, perhaps a little tighter than in an ordinary joint, so that the couplings will not start again. Then in the process of ordinary cementing the coupling is lined, and the next day, after the cement is partly set, the coupling is reamed out so that the end of the cement presents a square surface for the end of the next pipe to butt up against, our idea being to obtain a continuous cement surface. The question would come up whether, if the pipe butts too hard, it would not scale the cement off. We have never had any trouble with that; it is more of a grinding process. The movement and the ad vance of the thread pulverizes the cement rather than scales it off, so,

as we lay a pipe, we turn the water on and wash that powder out and there is no further trouble.

We try to have a pipe seasoned six months before it is laid. That insures better quality and also makes less trouble with tastes of the cement in the water. That is a thing we have to caution everybody about, that for a little while there will be trouble with that. But it is only from water that has stood in the pipe several hours. It is of no use to let a flow occur with the idea of washing it out, because it won't come out for some time at any rate. But, if the water is drawn out that has stood in the pipe for several hours, then the new supply will not be tainted.

As far as the quality of the pipe goes, we have used straight wrought iron. We have had a little experience with steel. Once in a while we get hold of a piece, but, with the difficulty of cutting and the occasional splitting of the pipe and the immediate formation of rust on the outside, we have never used it. Although its price is much in its favor, we prefer the wrought iron. As our soil is sandy, it is quite favorable, so that the outside of the pipe is not seriously attacked.

We use rigid connections exclusively, and have never had any trouble. In tapping the main, we tap it on the side and put a level on the shank of the tap so as to show that the tapping is level if it is desirable to have it so.

For lining, I have a sausage machine made by the Bell Company, 6 in. in diameter and about 18 in. long, a good deal larger than the ordinary. It is very convenient to operate. It operates with a gear instead of a screw. It is quicker to operate, and the pistons are fairly tight. I put a leather packing on them and change the nozzle at the head of the cylinder and put on a bushing so as to take any size from three-quarters up to two inch. It is necessary, in mixing the cement, to be very careful about it and to mix it thoroughly, — stir it all up, and the more time spent in mixing the better it looks. I heard some remarks here about cement dropping, but we have never had any trouble of that kind.

MR. J. C. WHITNEY.* Newton started in, on account of some experiments that were made, with the idea that, however bad other kinds of coated wrought-iron pipes might be, the galvanized

* Water Commissioner, Newton, Mass.

was the very worst, — that Newton water would probably take off the coating inside of three or four years, absolutely destroy it. The trouble was that the water they used in making their experiments was not the water actually used for the supply of the city.

They took plain river water, with the idea that it would come very near to being equivalent to the water which they intended to get, which was taken from the land adjacent to the river, and when the chemists reported that the galvanizing would disappear in the course of a very few years, it was taken for granted that they must use some other form of pipe. Lead pipe was expensive. Some people objected to it, of course. Brass pipe was out of the question. They tried experiments on various other kinds of coated pipes, and finally came to the conclusion that a tar-coated pipe, if some special pains were taken in the coating, would probably be the most satisfactory. They induced a firm in Boston to put in a vat, and subjected pipes to considerable immersion in a hot mixture, and they really did take special care, but I think the mistake that was made was in using $\frac{3}{4}$-in. pipe instead of 1-in. I really believe that if they had used 1-in. pipe instead of $\frac{3}{4}$-in., practically the whole of the services in use would be intact to-day. They used $\frac{3}{4}$-in., however, and when you get a quarter of an inch of rust, on an average, on a $\frac{3}{4}$-in. pipe, there isn't much space left.

After the works had been in operation eight or nine years, one of the inspectors took it upon himself to note the condition of the pipes in the houses where people had run a half-inch pipe, which a good many of them had done, from the cellar walls to the sinks, and found out the condition of the half-inch pipe in connection with the kind of pipe it was. He made a memorandum whether it was poor, fair, or good, and also the kind of pipe they had used. It was noted that the only people who were getting a satisfactory flow through that half-inch pipe were the ones who had used galvanized pipe.

The question was then raised by some one in connection with the works, whether galvanized pipe was not the best thing for us. A few experiments were made, and it was found that it was, so it was finally adopted, — about 1906, I believe. Since then prac-

tically nothing but galvanized pipe has been used except in cases where people demanded something else, as they do occasionally.

So far as I can discover, the galvanized pipe was the best thing for our water. Now we are using a 1-in. pipe, partly with the idea of furnishing ample water for any purpose and partly with the idea that, if the galvanizing does come off some day, we will have allowance for filling up. We never had to replace any galvanized pipe.

We endeavor to get strictly wrought-iron, galvanized. We occasionally have had a little steel pipe, but the galvanizing does not seem to stand very well, and it rusts much more rapidly than the wrought-iron.

We have all kinds of soil, and we are getting to have pretty well occupied streets, so it seems to us that there is some advantage in using the lead connection instead of rigid connection.

MR. R. J. THOMAS.* I want to go on record in favor of the rigid connection of service pipes to the main. In the early days of the water works at Lowell, in putting in the iron pipes they used the gooseneck, but for the last fifteen years, possibly, we have made our pipe connection on the corporation cock without a gooseneck, and find it gives us a great deal less trouble than the old gooseneck. Many of our leaks that we have from time to time we find occur on the gooseneck, and I can't recall a single instance where we had a leak on a service pipe where the connection was made direct and straight from the main pipe. If we meet an obstruction like a gas pipe, if it is in a large gas main, why, we have the gas company take it out of the way. If they don't do that — if it is too large — we bend the pipe; but we have not for many years made any connections with goosenecks.

I would also state that for the last fifteen or sixteen years, possibly longer, we have been using lead-lined pipes. We started in when they were first made because of the fact that the lead-lined pipe was cheaper than the lead pipe, — and we have got many services, hundreds of them, in use in our city, made of lead-lined iron pipe, that have given good satisfaction, and we have had no trouble with them, and with the rigid connection.

I have had experience with lead pipe, and I, like many other

* Lowell, Mass.

water-works men, believed in lead pipe on account of its economy and ease of handling. But there came a time when the water supply was changed to a ground supply that had a lot of carbonic acid gas in the water. This city had adopted, for a great many years, lead pipe. This city has over 12 000 services at the present time, and the first service, the No. 1 service on the book, is a cement-lined iron pipe, which was in use after forty years. In the interim they had adopted a lead pipe, and had put it in generally, and both the water department and the plumbers believed that that was the only proper pipe to use. But, as I said, there came a time when the water was improved; and in the improving of that water and introducing ground-water supply, tests showed after a while that this water attacked lead pipe. And then developed in some sections of the city — one particular section supplied by a particular ground water — a number of cases of lead poisoning, or supposed lead poisoning. The state authorities investigated it, and they almost issued an ultimatum to the department that any water that contained over .05 of one part in 100 000 parts was dangerous — and there was reputed to be one eighth. I don't know how true that is; it was reputed to be so. Although the water department combated that idea, the state authorities thought so. So, about that time, I believe, the State Board of Health doomed this lead pipe, and since then I do not believe that in a great many cities, in Massachusetts particularly, the lead pipe has been used without the sanction of the State Board of Health.

Mr. W. F. Sullivan.* The works in Nashua, N. H., were built in 1853, and for many years thereafter they put in the ordinary wrought-iron pipe. Then came the so-called enamel pipe and other kinds of pipes. For the last ten years we have used nothing but galvanized wrought-iron. I say wrought-iron pipe advisedly, because we trust that we get wrought-iron pipe all the time.

We use rigid connections entirely, and haven't had any trouble. The nature of the soil is rather loose and sandy. We can drive services under a street and sometimes wash them under a street. We use the 1-in. galvanized iron pipe, and think the life of the

* Superintendent Pennichuck Water Company, Nashua, N. H.

pipe will be as long as many of the older pipes that lasted anywhere from twenty-five to forty years. We think it pays to use the large diameter.

We use plug cocks in the cellar up to two-inch, and have some trouble inside in the cellar wall, the pipe rusting out and getting rather thin right there.

We furnish the pipe from the main to the street line, and charge the water taker for the portion of the line from the street line to the cellar. We put on a stop and waste and charge what it costs.

I think we ought to charge a little more than we do. We charge the bare cost. Being a water company, we make it as favorable for the water taker as possible. For thirty-five cents per foot we think we could do pretty well, on account of the easy digging. Before the rise in galvanized pipe, our services averaged from twenty to twenty-four cents per foot for inch services. That doesn't include the cellar cock, but includes the sidewalk cock.

Mr. George A. Stacy.* When we first started the water works in Marlboro we adopted cement-lined pipe for the services, and used it for perhaps eight or ten years. In that time there was more or less lead pipe used in the plumbing, and from the character of the inside of the pipe and the evidence of its use for ten or twelve years, and as the water for our additional supply that we were about building would be of the same character for generations to come, undoubtedly, I decided to try lead pipe. The wrought-iron pipe at that time had begun to give out in various ways, we had had trouble in the joint, where it rusted back. For the last fifteen years we have used nothing in the city of Marlboro but lead pipe. In all that time there has not been one case of sickness or disturbance in the human body in the city of Marlboro that doctors have laid to the lead pipe. That, to me, was the strongest evidence that lead pipe was a safe pipe for us to use there, knowing that the probability was that the source of supply and the character of the water were going to remain the same. I consider it the cheapest pipe to lay. When you lay it under a pavement, or in streets that you do not care to dig up, if you lay it heavy enough, under circumstances like those in our city, I consider it the best service pipe that is made. I consider

* Superintendent of Water Works, Marlboro, Mass.

the ideal service pipe to be a glass pipe, but they haven't got that very flexible.

If I was going into another place, I should be very careful what service pipe I should adopt. I would experiment five or six or ten years with actual use of the pipe, rather than trust to any analysis. I would rather judge it for myself. Of course we must say that cement pipe is safe, but if we are safe with something better, then let us adopt it. That is the way I look at it, and up to the present time we have won on that issue.

In Marlboro we found that the outside of the cement pipe gave us about as much trouble as the couplings, — the rusting back of the stopcock.

Mr. D. A. Heffernan.* In Milton we have about thirty-nine miles of service pipe, and in 1902 we changed from lead to cement-lined pipe. At that time I should say 75 per cent. of our services were lead pipe, and at that time we were taking Hyde Park water from driven wells, with more or less carbonic acid gas. In the year 1902, our water was condemned, and we had several cases of lead poisoning, — one fatal case, and four or five other cases through the town, — and a suit was brought against the town, and judgment, of course, was rendered for the plaintiff.

At that time, I looked into the service question, looking over the different materials to use, getting in touch with different superintendents and finding out their experience, and finally we decided upon the cement-lined wrought-iron pipe.

The average service is a 1-in. Byers' wrought-iron pipe lined with cement, to $\frac{3}{4}$-in. We line the pipe ourselves in about 14-ft. lengths. We use lead-lined couplings and the ordinary three-quarter flanged connection gooseneck. The average service is about 109 ft. long.

I am opposed to rigid connections. I always believed that there ought to be some allowance there for expansion and contraction. There is the case of running a pipe parallel with another which would cause some strain so that it would be apt to break off. A lead gooseneck allows for a good deal of expansion.

In regard to the inside of the cellar wall, I gave that thorough study and installed everything brass with the cement-lined pipe.

* Superintendent of Water Works, Milton, Mass.

I did not use any wrought-iron fittings at all at the meter. We find we have an absolutely good service, and consider it pays, for if we had had wrought-iron nipples it would be a case of filling up all the time, but by using the brass nipples we have a good clear passage and no corrosion at all in the cellar. The service is laid by the department, from the street main to inside the cellar wall. We use lead couplings. I claim that is a very important feature. Some of the superintendents use the cement-lined coupling. I am thoroughly opposed to it, because I think in making a connection the cement is apt to crumble, and in doing so it gives the water a chance to get in contact with the iron, and to have a chance for the collection of sediment, inside the cellar wall. This pipe is coated with graphite paint, two coats. We line our own pipes; it is done by the department men in about 15-ft. sections. Rosendale cement is used.

Two-inch cast-iron pipe can be used on long distances. We have been using it for twenty-five years, since I have been there, and that pipe has never given us any trouble at all. This cast-iron pipe, I might say, weighs 9 lb. per foot.

Mr. Allen W. Cuddeback.* I am, perhaps, one of those who have had the most experience of anybody in the Association with lead-lined iron pipes. I have been using them for sixteen years, and in perhaps as many thousand services. I am very much in favor of making stiff connections, — straight, solid connections from the main to the house, — and I have yet to have a single one of them break off. One of the principal advantages we find with the straight connection is that during these very cold winters when all of us have service pipes that freeze we can thaw it out in a few minutes. The doubt in my mind as to lead-lined pipe was, in the beginning, whether we could get continuous lead lining, and during the early years, the first eight or ten years of our use, I dug up, each year, two or three connections for examination. And the result of those examinations has led me to believe that in almost all of the cases you get a continuous lead lining if you are careful in setting the pipe up properly. And we have not had to renew any of our lead-lined pipes from choking up by rusting or other cause.

* Engineer and Superintendent Passaic Water Co., Paterson, N. J.

I have renewed thousands and thousands of both lead and galvanized-iron pipes within the last fifteen years, the life of which has been anywhere from twelve to twenty years. I find that lead pipe is attacked by electrolysis as readily as the iron pipe is, and becomes practically rotten and goes to pieces all over.

MR. GEORGE CASSELL.* My experience has not been very great with metals other than lead for services. We have used lead pipe in our city ever since the water works were installed. When we first started in, we used what was known as tin-lined lead pipes, but the water acted upon the tin, and the lead was so light that the pressure expanded it and there were a great number of leaks, so that we were forced to remove all of that and start in with pure lead. We use now nothing but $\frac{5}{8}$-in. pipe, $2\frac{1}{2}$ lb.

We used to use a coupling that was soldered on, but do not any more. We use the Anderson method. We used to use a goose-neck to allow the pipe a certain amount of play so that, if there was any motion, it would not break the cock off. Then we ran to the curb cock and put it on with solder just the same as we did the corporation, but now we do not do that; as I said, we use the Anderson method, which I have found to be very good. I have no fault to find with lead pipe, and in my opinion it is as good as any material that we can use. It has given a great deal of satisfaction. It is like all other work, — the material is always blamed where it should be the workmen that should be blamed, and not the material.

I have been forced to make a change, however, for the following reason: Since the fire of 1908 there has been a great deal of building, and when we run a lead pipe into a building — and that is the first thing they call for, because they want the water to use for building purposes — if the building happens to set on the line our method is to run the pipe to the line and push it through one foot for them to connect to. The builders connect to that end and either put on a hose bibb or a stopcock so they can screw a hose on, and they wiggle and they pull and they twist that pipe so that when they get through and the building is ready for occupancy the pipe is either broken or has been patched or is in a weakened condition. We have had a lot of trouble from that, so I was

* Commissioner of Water Works, Chelsea, Mass.

forced to make a change. I looked them all over and made up my mind I would try some of this lead-lined iron. So I got a little of it to try, and I am forced to think that I made a mistake in not using more of it before. I haven't had experience enough with it to talk to any length. I don't know what action electrolysis would have on it. I don't know what action frost would have on it. As to freezing inside, we all know that iron pipe or any pipe made of hard metal that has ice formed inside of it so as to expand will crack quite a ways and you have got to dig down and take out the whole length. With lead pipe we don't have to do that. If good lead pipe of standard thickness is put in properly, you have very little trouble from it. But you are going to have some trouble. But, whatever trouble there is, you can get down to it and remedy it quicker and with less work than you can in the case of the other materials.

Mr. William Naylor.* At Maynard we use cement-lined wrought iron, except that about fifteen years ago the American Woolen Company built something like one hundred and fifty houses and they wanted lead-lined pipe, so the superintendent at that time put it in for them. Now, I find the only trouble with the lead-lined pipe is inside the cellar wall, from the wall to the stop and waste. They rust out just the same as cement-lined pipe does. That is the only trouble so far that I have found with the lead-lined pipe.

My chief trouble with cement-lined pipe also is inside the cellar wall, from the wall to the stop and waste, so I have been putting a coupling on with a bushing and a $\frac{3}{4}$-in. brass nipple and put the stop and waste on that. I believe the coupling is so much heavier than the pipe that it will not rust so quickly, and as it is also cemented on the inside, I believe that it will help a good deal. I believe that an 18-in. or a 2-ft. piece of brass pipe from outside the wall into the cellar would obviate all trouble.

Mr. L. M. Bancroft.† We have been using the lead-lined pipe eighteen or nineteen years and have had no serious trouble with it. We have had trouble from electrolysis where pipes pass under the electric car track, and we have found the iron pipe com-

* Superintendent of Water Works, Maynard, Mass.
† Superintendent of Water Works, Reading, Mass.

pletely eaten away and the lead pipe left almost intact. It would stand until enough of the iron pipe was eaten away so that there wasn't strength enough in the lead to hold it. We have had one service that we have renewed four different times. We haven't had very much trouble from electrolysis in the last two years. The railway companies have been putting in better bonds, and have made some connections with their return wires, which has improved conditions greatly. We use the gooseneck in making the connection with the main. We have had a little trouble with the lead-lined service, which I presume might happen with a lead service, too; where the cellar had been built and the water turned on for building purposes, the pipe would freeze in the cellar, and then the attempt to thaw it out by building a fire under it would melt the lining and in that way close up the pipe.

I had one service, originally laid with cement-lined pipe, and in a few years it filled up. It was relaid with a lead-lined pipe, and in a few years that filled up. It was then relaid with a galvanized pipe, and that pipe has now been in use about eighteen years and we haven't had any trouble with it.

MR. W. C. HAWLEY.* This is a very excellent report, and I think one of the good features of it is that it points out the fact that the particular material for service line is to be determined by the particular conditions. You cannot make any general rule and say any one particular material is the material for general use.

I note, however, that the report says very little about the joints to be used in lead pipe. It has been my experience that that is the chief difficulty with the lead pipe. A wiped joint is a very difficult proposition to handle, especially where those joints may be made by any plumber that happens to come along, and for that reason I have ceased, for some years, to use wiped joints, and I am using one of the patented couplings, with excellent satisfaction. In our plant, some twenty-odd years ago, there were a certain number of service lines put in with one of the old-style patent couplings, one which has practically gone out of use. Those couplings are still in use, and we are having very, very little difficulty with them; none, in fact, except where they are disturbed.

Some fifteen or twenty years ago, I had occasion to replace a

* Chief Engineer and General Superintendent Pennsylvania Water Co., Wilkinsburg, Pa.

great many galvanized service pipes. Nobody seemed to know whether the old service lines were wrought iron or steel, but many of the old lines which had then been in service ten or fifteen years were still in a very good state of preservation, with very little rust, while many of the lines which had been put in within five or eight years were practically stopped up with rust. There was evidently some great differencce in the material in those service lines. When we get reports from one place that they are using a certain kind of pipe with fine satisfaction, and another place they are using that kind of pipe and not getting results, there may be some difference in the time when those services were put in, and the material of which they were made.

MR. MCKENZIE. We use galvanized-iron pipe for our services, and find a slight tendency to rust in the couplings. We have a supply of couplings on hand, and keep them painted on one side with a heavy elastic paint. When a job is put in, those couplings are put in place of those that come on the pipe, and I believe it is going to be a saving, in connection with the life of the service.

MR. A. L. SAWYER.* In Haverhill we use lead services altogether; that is, up to two-inch. We have taken up services that have been in use fifty or sixty years, and they are in pretty good condition as a general thing. I have been renewing services forty or fifty years old. In regard to cement-lined pipe, I have used cement-lined pipe for twenty years, and have found that cement-lined pipe itself is all right; it is good service pipe, but, after it has been in the ground eighteen or twenty years, the part that goes through the wall, about three feet, say, from the wall, is apt to be corroded. If it could be protected where it goes through the wall, it would last longer, but I think the whole outside of a cement-lined pipe should have some protection, should be painted with something or protected in some way from rust, for I have seen cement-lined pipe, which had been in eighteen or twenty years, where the iron would be all gone, and the cement would be the only thing that would be holding the water. A mere touch, of course, and it is gone. The trouble with corrosion is at the joints, they will corrode; but I think this makes an ideal pipe.

* Water Registrar, Haverhill, Mass.

MR. J. M. DIVEN.* Troy, N. Y., has used 1-in. cast-iron pipes, and after these have been in use probably from fifty to eighty years, they are giving trouble by clogging up. I would not recommend cast-iron service, even if it was in the market; in fact, I am taking them all up now. I presume that none are less than fifty years old.

Some further information on the subject of the use of the flange connection instead of the wiped joint, I think, would be of interest in connection with the discussion. I have used them myself about twelve years, and have never had any trouble with them. We have had trouble with poorly wiped joints.

MR. J. W. ACKERMAN.† At Auburn, N. Y., we use the flange connection, using 3A lead with brass ferrules, and we have never had one that leaked. Mr. Hawley says the wiped joint is an uncertain factor always. If I have a service pipe that leaks, I am always sure of finding the trouble at the wiped joint.

If a man needs more than a 2-in. service, he is very apt to need considerably more, and we put in a regular standard 4-in. cast-iron pipe, for any connection larger than two inches.

MR. C. N. TAYLOR.‡ We find, in towns throughout New England, almost every condition, all kinds of soil, and I have almost always used the lead flange connection and wrought-iron galvanized pipe. I have been doing this for something like twenty years, in many of the cities I have had occasion to look after, and I have had almost no trouble that is due to the action of the galvanized wrought-iron pipe. With that experience, I am inclined to continue to use those materials. It is a pretty good scheme to use material in water-works construction that is almost fool-proof, and that can be built by one not an expert, and which does not require a plumber to connect the joint. We have no fear that the work is not being done properly, the same as you do with the use of a lead-lined or cement-lined pipe. The ordinary piper will put a galvanized pipe together so that you can depend upon it. For small towns, where they are not able to have an equipment, and several men employed constantly, the lead flange

* Superintendent of Water Works, Troy, N. Y.

† Chief Engineer and Superintendent of Water Works, Auburn, N. Y.

‡ Contracting Engineer, Wellesley, Mass.

connection with the galvanized wrought-iron pipe is the best combination that can be used.

MR. W. B. R. MASON.* In Bound Brook, N. J., we have about eight hundred services; every one is a rigid joint. Perhaps our soil is adapted to that kind of a joint. We have no trouble with leaky joints.

MR. S. A. AGNEW.† We use in Scituate a lead flange connection, and strictly wrought-iron pipe. Now, whether the steel pipe is as good as the wrought-iron pipe, I am not prepared to say, but our works are only about fifteen years old, and we have not had time enough to test any one of our services to see whether or not one is going to last as long as the other. One of my chief reasons for using strictly wrought-iron pipe is because I find the use of steel pipe is the cause of profanity by my men. When they get hold of a piece of steel pipe, I find there is a good deal of swearing on the job, and for that reason, if for no other, I use the strictly wrought-iron pipe.

MR. A. A. REIMER.‡ It seems to me that rigid joints are applicable only in places where the service pipes can be run in a straight line. We are dealing with gas, electric conduits, telephone conduits, and there are all sorts of structures in our streets. If there is anything that is flexible, let us use it and keep out of the way as much as we can. That is the reason for my being in favor of the flexible joint, rather than a solid stiff joint from the pipe in, — to keep the street as free as possible from fixed structures so that the structures that cannot possibly go otherwise can have a little chance to go through.

In East Orange we use a flexible connection. In fact, we run the flexible pipe all the way to the curb line, and from there we change to a wrought-iron pipe, one inch, galvanized, all the way through to the cellar lines. We have no trouble with our wiped joints, and we have thousands of them throughout the city, about 8 500 connections, all told. We make our own wiped joints, regularly, and don't employ a high-grade plumber in doing it, either. We have a man who has come up from the trenches in

* Superintendent of Water Works, Bound Brook, N. J.

† Superintendent Water Works, Scituate, Mass.

‡ Engineer Water Department, East Orange, N. J.

our work, and has learned to wipe the joints, and does it regularly, and they stand up successfully.

MR. C. D. SHARPE.* We have now in the Putnam plant 1 070 services, counting all sizes. Our ordinary house service is three-quarter inch in size, although services of sixty or more feet in length are one inch, in many cases. In making the connection, the nipple is wiped on to fifteen inches of 3-lb. lead pipe, with a female solder nipple on the other end, which makes a gooseneck about 20 in. long. The service pipe is screwed into the gooseneck, and just back of the curb line we put in a curb cock, with a Bingham and Taylor curb box over it. The pipe is carried through the cellar wall four inches or more, and a stop and waste put on, with a union on the cellar end.

At the inception of the water company we used enameled wrought-iron pipe, made by the Providence Enameled Pipe Company, and it certainly was good pipe, quite a lot of it still being in use. As time went on, we thought the quality was sacrificed on the reputation made, and quit the use of it and took up lead-lined pipe in 1908 and 1909. We have found this to wear very well, and have replaced but few of the services laid with it; but we had some trouble making the joints, as the lead would be loose, in short pieces. This has been remedied since, so the lead cannot be separated from the iron, excepting by heat.

Since using the lead-lined we have used wrought-iron galvanized pipe with fairly good success. We have had more or less trouble with pipes filling up, where iron and brass came together, caused, I suppose, by galvanic action of the two metals. By letting the pipe protrude through the wall four or five inches, it gives a chance to cut another thread, if the first rusts off, and I have noticed that in some cellars the pipe deteriorates much more rapidly than in others.

Our brass goods have always been the same style, viz., Newport stops, Fitchburg stop and wastes, and a heavy corporation cock, and all full size, round-way opening. We have not varied from this style, for I have appreciated the fact that when you dig up the main you know what you are going to find and have more like them if they need replacing.

* Superintendent City Water Department, Putnam, Conn.

I also appreciate the efforts that this Association is making to standardize different things in common use, and I hope to see the day when ¾-in. meters, and less sizes, of all makes, shall all have the same size spuds and threads and all be the same length, so that one can send out a man to change a meter, carrying the new meter and two wrenches, rather than carrying couplings, short nipples, and die stock and cutter, for fear it will be either too long or too short.

Mr. C. L. Baker.* About a year after I took charge of the Abington Water Works, I changed from cement-lined to galvanized wrought-iron. The trouble I found with the cement-lined pipe was that it wasn't properly lined. I had a good deal of trouble for the first year. I presume it was the fault of the man employed to line the pipe. The pipe was unevenly lined, and it flaked off. There were places where it wouldn't be more than one-eighth of an inch thick, and the water would get under it and of course throw it off.

The couplings were unlined, and they would fill with rust and then the water would get under the cement next to the joints and it would be thrown off, and plug up the pipe.

I use galvanized wrought-iron pipe, the best I can buy, because of the fact that I know of some places where there was steel put in previous to my taking charge of the work which lasted only five years. I use a 1-in. pipe, and in case of two-family houses I use a 1-in. corporation.

Mr. Horace Kingman.† In Brockton we have been using cement-lined pipes for pretty nearly since the works started, — thirty-six years ago. We now use nothing but galvanized wrought-iron, cement lined.

I don't think you are sure of getting as uniform pipe in steel pipe as you are in wrought iron. There is a difference in cutting threads if you use commercial dies. You can have dies made that will cut steel and iron equally well. There is no difficulty that way, — only you have got to use a different die for cutting steel than you do for iron.

In lining the pipe we first bore the pipe, drive a cutter or plug

* Superintendent of Water Works, Abington, Mass.
† Superintendent of Water Works, Brockton, Mass.

through to take the burrs out, and then we change the coupling over, and line as they ordinarily do. Of course, it is possible to have the pipe already cored or bored if you want to, but when we have had bids we have found that we could do it cheaper ourselves,— possibly not so well but well enough, and cheaper.

The couplings are turned so that we may be sure that they start on the pipe right, and then there is a nipple put in the other end of the coupling of the same size, and the lining run up to that.

MR. A. F. HART.* I have noted that with each of the different kinds of service pipes that we have in Saugus there seems to be some trouble, and it is only a question of picking out the one that has the least trouble. Up to four years ago, we had used cement-lined pipe, lead-lined pipe and some galvanized. The cement flaked off and bothered a great deal. It may be that was in the fault of the construction, — I don't know. The lead-lined pipe corroded on the outside very badly. We had some that had been in only about four years and we had to take it out on account of corrosion from the outside. That may be due to the soil. We now lay nothing smaller than 1-in. services.

We now use enameled pipe. The pipe is dipped two or three times, allowed to dry each time, run into an oven and baked, and when it comes out it is almost impossible to scar it even with a wrench; in bending, it never flakes or chips off. It is perfectly elastic. We have tested it in as many different ways as we could, to get as nearly the effect of years as it was possible to, and compared it with all the other brands that we used, and it certainly showed the brightest of anything.

It costs ten cents a foot, landed in Saugus. I buy Byers' 1-in. black pipe, and have it enameled. It comes back just as smooth inside as a piece of glass. It looks like the enamel they put electric wire into, but the coating is much thicker and the preparation is different.

I have had it three years. That, of course, is a very short time for pipe, but it is all just as bright as when it was put in. Of course, enameled pipe is not a new thing, but we think this an improvement over the old type of enamel.

* Superintendent of Water Works, Saugus, Mass.

MR. GEORGE H. FINNERAN.* Those of us who are concerned with the sizes of the pipes ought, in my opinion, to examine into the conditions very carefully when application is made for a supply, in order to determine the exact requirements and grant no larger size than is really required, — because of the consequences.

The consequences of over-sized pipes are several and expensive. First of all, the larger the pipe, the larger and more costly the meter; and the repairs of a larger pipe are more costly than those of a smaller one; the loss of water from a leak or a break is greater, and the damage which is apt to result to property is also greater usually. More important than all is, as Mr. McInnes graphically described in his paper on the Salem fire,† in the case of a conflagration where a building collapses and the pipe is broken off, the loss of water there brings the pressure down in a street to a point where it handicaps the fire department.

MR. J. C. CHASE.‡ My first experience with service pipes was in the use of cement-lined; this was abandoned to a certain extent on account of the trouble of putting them in. It is an ideal pipe if properly made and properly laid, but a difficult one to get labor to handle in the right way. Another vulnerable point was that they were not careful about getting an intimate connection of the cement at the couplings, and very soon it would corrode and stop the flow. Then several kinds of protected pipes, like rubberoid and tar-coated, were in use. I think that the lead pipe is the ideal pipe if you can get rid of the sentiment against it, and I think in nine cases out of ten it is nothing but a matter of sentiment, as being deleterious. But if you are not going to use that, you have got to determine the character of the water and take the next best thing.

MR. T. G. HAZARD, JR.§ We have had occasion, recently, to set back some of our service boxes, owing to the fact that when they were first put in there were no curb lines established. Our services were all lead. We lay our services to the curb line, and the householder ordinarily carries a galvanized-iron pipe from the

* General Foreman, Water Service, Boston, Mass.
† JOURNAL N. E. W. W. A., *XXIX*, 94.
‡ Derry Village, N. H.
§ Civil Engineer, Narragansett Pier, R. I.

curb line to the house. Our method of extending these services is to dig up the old curb box and cut off the galvanized-iron pipe, and extend our service one or two feet, or whatever it is necessary. We find in a great many cases that these galvanized-iron pipes are so rusted up that it is impossible to cut a thread on them, they are so far gone.

Mr. McBride.* We found that a cement-lined pipe will do very good work, but that the joints are likely to be troublesome. Of course when you line the pipe and the coupling together, and then cut back the cement as has been described, for five or six threads, you try to keep that cement flush and square with the center so that when the pipe comes in it will meet. But it is always guesswork; of course we cannot see on the inside of it.

We took some short pieces of pipe, about a foot long, so that we could look into them, and before putting them together we put some cement in the coupling. We used Portland cement in that case. Then we had a rubber ball on the end of a wire which we put into the pipe beyond where we were working, and screwed the pipe up tight, — the idea being that the cement would squeeze out into the thread and between the two ends of the pipe, out into the inner pipe. Then, after we had finished with that, we drew the ball forward, and that gave a wipe of cement which closed up the crack completely. Then we pushed the ball back once, and drew it out with the residue of cement. After a day or two, we cut the pipe very close to the coupling, and we found that we had an absolute surface of cement right across. I thought this might be interesting, because I haven't heard it spoken of before. I don't know that it has ever been tried. We have pipe supplied to twenty-two feet of length, although we have it down to fifteen. If you are using that length of pipe, you can take a wire with a rubber ball and then put in your cement and draw it through. I think you will find in nearly every case that your cement will be in there and you will have a perfectly joined cement pipe.

Mr. A. E. Martin.† Springfield, Mass., uses rigid joints, and has for thirteen years, and I don't know how long before. When I went there, I found that they had adopted that plan.

* Of the Macbee Cement-Lined Pipe Co., Boston, Mass.

† Superintendent of Water Works, Springfield, Mass.

That was thirteen years ago. We never have any more trouble with the rigid joints than we used to have in a smaller place with lead connections. I consider it a success.

I think that the general opinion of any one who taps a water pipe is that it is a good deal better to push the corporation in a quarter or half inch into the pipe than it is to leave it flush. You are going to have a lot of trouble if you leave it flush absolutely. We once in a while find, in my experience, a corporation that is tapped part way in, not quite through. The hole, of course, is tapped through and we get a complaint that they can't get any water. I have in mind one that happened about three months ago. The service pipe had been in about twenty-one years, by the way, and we knew from experience that it was probably filled up some; but if we had dug up the main and cleaned that corporation, we could have prolonged the life of that service pipe I don't know how many years. In putting in the new service we found the corporation was plugged up.

In regard to the corporation cocks which extend into the pipes when a pipe cleaner is used, I would say that I have asked that question of the pipe cleaning manufacturers and they say there is absolutely no danger,— the cleaner will pass by in every case.

Mr. G. E. Winslow.* In 1884 or 1885 I used cement-lined pipe, and to protect the coupling I put a piece of pipe perhaps fifteen or eighteen inches long into it, with a couple of threads. Then I pushed the cement into it, and I had two cones, one eleven or twelve inches long, and another one back of that; one to go to the center, the other as a follower. In pulling that through, the cement would come through into this coupling and against the piece of pipe that was left. That left the coupling lined with cement. I had never taken any of that pipe out until this last summer, when I had occasion to change the meter, and the stopcock on the end had to be removed. I had a piece about four feet long outside, because I had seen that the pipes inside the cellars, nearer the stopcocks, and more especially that exposed to the air and dampness, would rust more or less. In some cases I have seen pipe put through that way and painted, but mine was not painted. It broke off, so they had to dig out a little way,

* Waltham, Mass.

and they took off this piece of pipe and the coupling was there lined in the way I speak of, with no rust whatever. So I thought that as it had been lying there for twenty-nine years, and the pipe was in good condition, my theory was all right.

MR. D. N. TOWER.* In Cohasset we use galvanized iron in most cases, but lead pipe if near salt water. At first we put in a few cement-lined services, but we are so near salt water I was afraid the pipes would rust through from the outside, as they were not galvanized. There is trouble with corrosion on the outside where the pipe is near salt water or laid in ashes. I am beginning to have trouble inside the cellar where the shut-off screws on, where the thread is eaten away by the action on the metal. At the beginning I didn't allow the services to extend through the wall far enough to cut a new thread, so that necessitated digging up outside and putting on a piece; so now I am careful to let the pipe extend through far enough so that I can put on a new thread. Then I put on a brass nipple back of the shut-off.

We have always used lead connections, as it is so much easier to change the direction of the service.

I made a mistake when our mains were laid in an unusually dry summer by laying them so deep that the ground water in some cases was above the main. I have to dig to get down to the tap, and bend the lead connection up to the service.

I have, I suppose, more shutting off to do than most places on account of the summer people. I found that it is better to set my shut-off cock on the lead connection, as shutting off and turning on every year starts them leaking, and it saves digging up the ground in two places by having the shut-off and corporation at one place.

MR. G. T. STAPLES.† The works in Dedham were constructed in 1882, and we laid common enamel pipe. Of course, it filled up and leaked at the couplings, and the threads rotted off and we had a good deal of trouble. Then we adopted cement-lined pipe. We have had some trouble, but most of our trouble has been with the goosenecks. We put in a brass nipple that was very light, and our water is very hard on brass and it leaks through it.

* Superintendent of Water Works, Cohasset, Mass.
† Superintendent of Water Works, Dedham, Mass.

We use the Rosendale cement for lining. That is what they started before I came there and I kept on using the same thing. I never had any trouble with it. The couplings we line with lead. There is one advantage with the lead couplings; the lining gets in between the two pipes and when they are screwed up and protects the whole thing and keeps it from leaking. It is just the same as using a lead washer. We use Byers' wrought-iron galvanized pipe, cement lined. I have tried all the other pipes, but they don't seem to run uniform.

In regard to bending cement-lined pipe, I agree with Mr. Forbes. I have bent pipe to right angles and then sawed it in halves with a hack saw and the cement was just as good as ever. I would not have believed it until I had done it.

Mr. G. F. Merrill.* Our plant at Greenfield has been in since 1872. The original service pipes were of wrought iron. Since 1907 we have used galvanized pipe, strictly wrought iron. Previous to 1907 all the connections were made rigid, with no gooseneck at the main. I took a service out this last season that has probably been in since the works were installed.

We have had a good many leaks with the rigid connections. It is hard to account for all of them. Quite often in the fall of the year, perhaps about the middle of December, we have more or less trouble of that kind. It seems to me it is more pronounced at that season of the year, when the frost is getting into the ground, or perhaps a change in temperature in the water.

It used to be customary to tap the main on the top with a rigid connection, — tap it exactly on the top and use an elbow That elbow would be turned in the direction the pipe was laid, of course, and any strain on the service pipe near the main would break the cock. A good many troubles of that kind we found were caused by excavation of trenches near the main, either for sewers or gas or other sort of work. We invariably found that if the back filling was not very carefully done, when that filling settled down its weight would break off the cock on the main. Since we have adopted the lead gooseneck we have avoided that almost wholly. The gooseneck we now use is one that we make ourselves. We use lead flange brass fittings, similar to the Mueller lead flange fitting, and buy a lead pipe and make it up at the shop. The

* Superintendent of Water Works, Greenfield, Mass.

gooseneck is made with a tool that we get up ourselves. It simply turns out the lead and flanges it down. We find a man can make them very rapidly on a machine of that kind.

Once I used some of the goosenecks that were made with the soldered nipple and a union at the end that attaches on the main. They were supposed to be sweated in, but we had some trouble with them when excavating near the main; the solder being somewhat brittle, if we strained a pipe it would leak at that point. We have better results with the lead flange gooseneck because it is absolutely solid right up to the base of the union, and when it is made up tight, there can be quite a little movement of the service pipe without starting any leak.

We use a three-quarter-inch service, but I think the use of a one-inch service would increase the life very materially. The difficulty would be the little additional cost. Most, or a good many, new buildings are built by contractors who take the whole contract for the building and the water supply from the main, and they look pretty closely at every penny that is expended on the water service.

At present, our rules require that we lay the service to the street line, and where the owner desires it we lay it up to the cellar wall. In most cases they ask us to lay it up to the cellar wall.

I think all water works should have complete control of the service right up to the meter. An illustration of that is perhaps a condition that I found in my services when I first went to Greenfield. At that time the services were owned by the owners of the property and paid for to the main. It had been customary, ever since the works were established, to allow every owner to put in his own service. He either employed a plumber or employed laborers and did his own plumbing. The water department furnished the curb cock and sidewalk box, and they set the boxes promiscuously, sometimes inside their own land, sometimes in the street, and the services were put in without much system. Another feature that is bad, particularly with contractors who are building a house to sell,—they seldom excavate more than two feet deep for the service, which causes a lot of trouble about freezing, or else you have got a condition where you have to allow the water to run continually to prevent it from freezing.

I think one good feature of using the lead gooseneck is being able to drop your pipe quickly to get below the danger of freezing, and the other feature is quite a saving in time for the man connecting a pipe up in the street.

I believe we shall adopt the cement-lined pipe as soon as we have facilities in the shop for lining it.

MR. P. R. SANDERS.* At Concord, N. H., we have always used black wrought-iron pipe, cement lined. Our main trouble has been where the corporation was screwed on to the service pipe at the main, and also at the curb valve. We have been troubled with corrosion forming from the iron right in to the curb valve, and also on the female connection on the corporation. The same thing would happen in the cellar. The cement-lined pipe has worked so well with us that it seemed to me that the thing to do was to get something that would do away with that corrosion as much as possible. For the past two years we have been using a thimble that we put inside, after reaming out the cement a little bit, and I think this is going to stop the trouble. The thing you have got to do, in my opinion, is to stop the water from getting at the end of the iron pipe. If you can stop that, you are stopping your pipe from rusting away from the inside back to the valve.

We use lined fittings exclusively. We originally used a plain coupling, that is, the coupling that ordinarily comes with the pipe, but we have substituted driven pipe couplings, because very often we find the ends so battered that it is almost impossible to catch a thread. With the driven couplings we never have any trouble.

We have been lining our pipes with Portland cement for the last four or five years and have no trouble.

The property owner looks after his own service pipe from the street line. As a general rule, he will put in galvanized pipe of the size that we use. It is not laid under the supervision of the water department. The only thing we insist upon is that the owner's pipe shall be laid at the proper depth.

MR. L. R. DUNN.† The old Revere Water Company, which

* Superintendent of Water Works, Concord, N. H.
† Superintendent Water Department, Winthrop, Mass.

laid the main pipe, installed cement-lined services in 1885. I went to work for the department in 1890. We didn't begin to get any trouble with the cement-lined services until after we began to use the Metropolitan water in 1898. Then we began to have trouble with the fittings on the cement-lined pipe. The water company used galvanized fittings, and they became packed completely full of rust. We had no trouble with the cement-lined pipe, because after we removed the fittings, the pipe was apparently all right on the inside, but wherever we used those galvanized fittings, we found trouble.

After the year 1900 the company stopped making the cement-lined pipe and they used galvanized pipe and got into worse trouble than before. In 1909 we abandoned the use of galvanized pipe, and since that time have been using nothing but lead.

MR. H. P. PLIMPTON.* In 1896, Walpole used three-quarter-inch lead-lined pipe and had trouble at once. The pipe plugged by water getting under the lining. We now use for services plain wrought-iron pipe lined with Portland cement and beach sand. More or less galvanized pipe is used by the owners; and while we do not advise its use, we cannot prevent it, as we allow takers to put in their own services, but if they have any trouble from it, they pay for it in the end.

Different cements require different amounts of sand. We are very particular in the way the pipe is handled. We don't allow a pipe to be bent at all, and don't allow a man to carry one length of pipe on the team, but tie three or four of them together so that they will not bend.

Wherever we have to cut the pipe and use a fitting, we use a composition coupling or union. We haven't had any trouble from pipe corroding around the fittings.

We have trouble with our pipe rusting out through the cellar wall, and have found no way to remedy it except by putting in a three-foot piece of brass pipe, and that costs too much for most people. I put it into my own house and I would like to put it into all. I don't believe it is possible to prevent iron pipes rusting in the cellar.

* Superintendent Water Works, Walpole, Mass.

MR. FRANK B. WILKINS.* In Milford we have used cement-lined pipe for twenty-four years, and personally I have for fifteen years, and we have had very little trouble with it. Our town, while small, doesn't wish for anything else but the cement-lined pipe. We use the gooseneck. But as far as lead pipe or lead-lined pipe is concerned, they would not tolerate it a minute in the town. Our goosenecks are only twenty inches long, but some object to even that amount of lead being put into the system. We have very good success. They have been frozen up during different winters, but they have not to any extent given us trouble by opening up so as to give us a leak. In many cases they have thawed themselves out and have run for years afterward.

MR. F. L. FULLER.† The works at Wellesley were built something over thirty years ago, and at that time of course there was not as much information as there is at present. We used tarred iron pipe, and it lasted about a dozen years, and then became filled with corrosion and rust. We then adopted cement-lined pipe, and have used it ever since with excellent results. We have services that have been in twenty years that are just as good, apparently, to-day as they ever were, and when for any reason a piece of this pipe is removed, it always appears clean, and there has been very little trouble with the corrosion on the outside of the pipe.

So it has seemed to me that there was no better pipe than the cement-lined pipe. As has been said, it should be carefully made, because it must be properly and thoroughly filled, and proper cement must be used, and care must be used in handling it. All those things contribute towards a good pipe, but it seems to me it would pay for any department to use this care in making their pipe and laying it, because when a service pipe is once in, in good condition, it is there to stay for a good many years.

MR. PATRICK GEAR.‡ The service trouble that the gentlemen have spoken of is the same in Holyoke. We have all kinds of services there, and all kinds of pipe.

This week we have been taking out some service pipe that has

* Superintendent of Water Works, Milford, N. H.
† Civil Engineer, Boston, Mass.
‡ Superintendent of Water Works, Holyoke, Mass.

been in for forty years, owing to the repaving of a street. I couldn't tell whether it was galvanized pipe, or what kind of pipe it was, but it is in pretty good condition to-day on the outside. In 1892-93 they used to tap the pipe and put in a short brass nipple about six inches long, and screw a stopcock on that. We found that most of these are worn out, so we take them out.

Whether the service pipe is a galvanized pipe, or a lead-lined pipe, or a common iron pipe, with any coating on the inside or the outside, when you cut a thread in it you will have the iron exposed. The only place that the service pipes give way is where they are screwed into the stopcock. We use lead-lined pipe almost entirely, but we use some galvanized. We have some pipe that has been in for forty years and has given good service, and we have had the same kind of pipe in there for twenty years and then have had to renew it.

Every time we find a gooseneck, we take it out. Our gooseknecks that we had in years gone by were put in probably around 1880, and we have had a lot of trouble with them. They used to have a white paint on them, and we had more trouble with that connection than any other connection we had. Then they used to make what they called tinkers' joints, and some of them gave a good connection.

As far as our city is concerned, we do not have any rock or anything to contend with. The telephone people and the gas people come along, and they put their meter or their pipe where they want to, but the water man has to take what he can get. In going into a building they say: "We will have the coal bin here, and the stopcock will be in the coal bin, and if it breaks, shut it off in the street." The water man is the only one who does not get any consideration at all from the man who is building the house. The gas man will have his meter up near the window, and the water man has to go down under the stairs with his meter. if he has one.

We have done away with all three-quarter services. We take the service from the curb to the cellar. The old-fashioned stop and waste that they have in the cellar, that a woman could never shut off, we have done away with, and we now use a wall valve. We put in a plugged tee, so if we have any trouble we take out

the plug and run the machine through and clean it, with a rigid connection clear to the pipe. We don't let any plumber interfere from the main to the cellar.

MR. R. S. WESTON.* I have had very little experience in laying service pipes. I have had considerable experience, however, in protecting them from corrosion. There now seems to be a universal belief in the use of three kinds of pipe, cement-lined iron, galvanized or zinc-lined iron, and lead. I want to emphasize what Mr. Hawley has said, that it is the kind of water that should determine the service pipe. There is no reason in the world why, with a fairly low colored surface water, one should not use galvanized iron, a good grade of wrought iron, or a good grade of steel if he wishes, because you can have good iron and bad iron and good steel and bad steel. Bad iron is far worse than bad steel.

There is also no reason why you should not use lead pipe, where the water forms a protective coating on the inside of the lead. In all other cases, I think the cement-lined pipe ought to be used. I am speaking now from the standpoint of the quality of the water furnished to the service.

A rather peculiar case came to my attention three years ago. The town, which had suffered somewhat from lead poisoning, put in a filter; changed from a ground water supply to a filtered surface water supply. The surface water soon accumulated organic matter enough in the filter so that the water coming through the filter corroded the lead pipe far more than the ground water did before. The remedy in that case was to put lime in the water, and the corrosion was reduced to practically nothing. The reason, of course, for corrosion is acid, and where water is filled with carbonic acid or vegetable acid, the plain iron must be protected by cement or lead, or lead pipe must be used. I have never heard any superintendent speak of any trouble because of well-made cement-lined pipe.

I should like to emphasize one thing that Mr. Stacy has said, regarding the inadvisability of placing too much reliance on laboratory tests of pipe with the water in question. I know of one case where a water company is being seriously embarrassed

* Of Weston & Sampson, Consulting Engineers, Boston.

because the water attacks the lead pipe. And there is one case in this city in particular where the lead poisoning was so severe that the blue lines appeared on the gums, and lead appeared in the secretions, and all the other symptoms of lead poisoning occurred. Yet that water when tested in a bottle for six months showed about a third the capacity for absorbing lead as did the Metropolitan water, and we know that the Metropolitan water has no great capacity for attacking lead. Therefore I wish to emphasize Mr. Stacy's remark that you must take the physical character of the water into consideration, as well as its effect in bottle experiments.

MR. C. D. HOWARD.* I may say that most of the service pipe in use in New Hampshire is galvanized iron. Quite a number of supplies are, however, delivered through cement-lined pipe. There is considerable complaint as to the durability of the galvanized-iron pipe, and we very frequently have occasion to suggest the use of cement-lined as calculated to be more satisfactory in such cases. I have of late tried to gain information as to the availability of some brand of pure iron pipe, but such does not seem to be on the market.

The city of Manchester uses lead-lined pipe. There is still quite a good deal of plain lead in use, as well as some tin-lined lead, although the latter is not being installed very much nowadays.

We have always made a practice of determining the lead in every sample of lead-conducted water submitted to the laboratory. As a result of our reports, a very great many of the older private supply systems have been changed over to iron. A great many cases have been encountered where this water showed 0.05 parts per 100 000 up, and in a great many cases where the analysis showed less metal than this there seems to have been pretty definite clinical symptoms of lead poisoning in one or more members of the family. Now and then these symptoms have been confirmed by the urine examination. At the same time, we have never thus far attempted to collect and arrange these cases in an investigative way. In many instances, of course, there is room for considerable question as to whether or not lead is actually responsible for the symptoms noted, it being but natural for the

* Chemist, State Board of Health, Concord, N. H.

attending physician to invoke a scapegoat of this character when the indications were otherwise obscure. At the same time I am satisfied that there has been a good deal of health impairment in the past due to the use of water containing small amounts of lead, and I am convinced of the desirability of the abandonment of this variety of service pipe.

MR. F. N. SPELLER. The conditions which influence corrosion of services are radically different on the inside and outside, and require, therefore, different treatment to secure the maximum service. These protective measures should be designed to suit water and soil conditions, as previous speakers have pointed out.

In considering outside corrosion by itself, it seems that the long experience of gas companies should be of practical value. The usual practice is to use a bituminous paint, preferably applied on a priming coat of coal tar in benzol, or this reinforced with one or two layers of coarse cotton fabric saturated with asphalt or coal-tar pitch, tightly wound spirally on the pipe. In particularly bad places, a rough wooden box may be built around the pipe and filled in with cement concrete thoroughly worked. Most gas services, however, receive very little protection. It would seem of practical advantage for local gas and water men to get together on the question of what pipe protection is needed for their particular locality, as the conditions are identical. It will probably be found that protection will only be needed on a small proportion of the lines after a thorough survey of the district is made. The system of wrapping the pipe in saturated fabric is used quite extensively out West, on water and gas lines. The expense of this coating is about one cent per foot per inch of diameter.

The large majority of gas and oil companies now use steel pipe, having found by careful observation in comparison with wrought iron that the service is at least as good. The reference given below to this subject in the proceedings of the American Gas Institute may be interesting to water-works superintendents who are looking for light on this question of iron versus steel.*

A recent analysis of pipe being purchased by gas companies in

* Proceedings of the American Gas Institute, Vol. 3, pp. 265, 274; Vol. 6, Part 1, pp. 318, 348, 351, and 357; Vol. 8, Part 2, pp. 145, 154, 191, 212, 216, 223, and 259; Vol. 9, p. 1065.

105 localities in New England showed the following, which I believe is representative of the present trend. While there are no figures on record, it is safe to say that the per cent. of wrought iron used ten years ago was very much greater.

		Per Cent.
Those using steel pipe exclusively	75	71.42
Those using steel and wrought iron	13	12.38
Those using wrought iron exclusively	15	14.28
Unknown	2	

Extract of paper by H. L. Rice, from abstract entitled, "Installation of Mains and Pipe Lines, Steel and Wrought Iron," Vol. 8, p. 146:

"The question of wrought iron as against steel seems to come down to the relative corrosion, and the consensus of opinion of a number of authorities quoted seems to be that there is little or nothing to choose between the two."

Taking the country as a whole, the official records of the American Iron and Steel Institute show that about ninety per cent. of the oil and gas pipe is steel. (See Bulletin No. 3, American Iron and Steel Institute, 1917.)

As to internal corrosion, it has been well brought out in previous discussion of your committee's report that this depends principally upon the character of the water. New pipe carrying filtered water is subject to comparatively severe conditions, as the natural protection obtained from the organic matter and silt deposited from unfiltered water is lacking. I was not disappointed, in listening to the discussion, to find there were still a few in New England who favored wrought iron, but I did expect to hear more details as to the basis for such opinions. The subject of corrosion involves so many factors that it has been found unsafe and misleading to depend on isolated experiences other than comparisons in service where both materials have been put in the lines together at the same time. The identity of the material should be determined by some one accustomed to making tests of iron and steel, for it frequently happens that what is taken for steel pipe turns out to be wrought iron, and vice versa. Judging by some of the experiences related, it is surprising that any money should

be wasted on coating wrought-iron pipe for service lines. I am now connected with a company which had its beginning in making wrought-iron pipe in Boston about fifty years ago. Probably this company is responsible for some of this good old material which has been fortunate enough to survive, and also for a good deal more that has disappeared due to less favorable conditions. We were never able to connect long life with any particular mix of iron, but did finally determine beyond a question or doubt that steel could be made just as durable as wrought iron. This took a generation of experience. Most of the comparative tests of wrought iron and steel have been made with hot domestic water supply, where the rate of corrosion is much more rapid. More than one hundred service tests have been run by placing several samples of different kinds of pipe in the same line and examining the inside of these pipes after a few years or after the line started to fail. All who have made such tests agree that the difference was very small — usually, however, in favor of the steel pipe. There is no apparent reason why the same conclusions would not hold good, using the same water unheated.

One reason for the opinion which is held by some New England men on this question of pipe is probably due to the lack of a standard weight of pipe. Until a few years ago, steel pipe was made in various weights for various purposes, and substitution of lighter weights was easy. Now, to prevent this, all wrought-iron and steel pipe is made full weight. When steel pipe was first made, only a few of the mills had facilities to make the special quality of uniform soft steel required to give the best results. Many attempted to make pipe of steel purchased on the open market, which is usually very unsatisfactory.

There is a larger proportion of wrought iron in use in New England than in any other locality, but the figures which I have given in the early part of this discussion indicate that the same tendency prevails in New England, for ten years ago the spirit of reverence for what is old and tried was so strong that the per cent. of steel pipe in use was very much smaller.

So I would suggest, if you have strong opinions on this question, to look over your evidence and determine whether your opinion is based on comparative service under like conditions and on enough instances to be fairly representative.

The following records compiled by the American Iron and Steel Institute illustrate the trend of the times.

PRODUCTION OF IRON AND STEEL SKELP IN THE UNITED STATES.

Year.	Iron.	Steel.	Total.	Per Cent. Iron.	Per Cent. Steel.
1905	452 797	983 198	1 435 995	31.5	68.5
1906	391 517	1 137 068	1 528 585	25.7	74.3
1907	444 536	1 358 091	1 802 627	24.6	75.4
1908	297 049	853 534	1 150 583	25.8	74.2
1909	370 151	1 663 230	2 033 381	18.2	81.8
1910	350 578	1 477 616	1 828 194	19.2	80.8
1911	322 397	1 658 276	1 980 673	16.3	83.7
1912	327 012	2 119 804	2 446 816	13.3	86.7
1913	312 746	2 189 218	2 501 964	12.5	87.5
1914	264 340	1 718 091	1 982 431	13.3	86.7
1915	262 198	2 037 266	2 299 464	11.4	88.6

MR. JAMES ASTON.* I am here as an advocate of the use of wrought iron. Mr. Speller speaks about many tests disclosing the fact that steel is just as good as wrought iron. He says also that we should not condemn some of the earlier installations, because the steel at that time was not as good, perhaps, as the steel which has been made to-day. I think there has been progress made in the quality of steel by the National Tube Company, but on the other hand I think it is unfair for Mr. Speller in the next breath to refer to tests of wrought iron and steel, and then to condemn wrought iron as a class, because we can show conclusively that a large part of this wrought iron is not the article in the true sense of the word. It is an adulterated material. Therefore, in comparing wrought iron with steel, he may be condemning the poorer quality of the material.

It is surprising how much of the wrought iron which is on the market to-day is an actually adulterated material in every sense of the word. The effort to get into competition with steel, or the effort to get under the other man making wrought iron, has led to the use of scrap, which is very heterogeneous, even though there is some selection. Then there is the deliberate use of steel mixtures, which remain as such in the final product, and give a

* Metallurgical Engineer, Pittsburg, Pa.

decidedly heterogeneous material, which is not wrought iron in any sense of the word.

I am just as firm an advocate as Mr. Speller of the galvanized product, because the protective coating is certainly worth something. We believe galvanized wrought iron is superior to galvanized steel. So far as the coating itself goes, the character is the same in both cases, but in the case of wought iron, we have the advantage, we claim, that there is an initial roughness to the material which gives a greater penetration to the coat, and a greater thickness to the coat. So, from the standpoint of the like size pipe, wrought iron has a heavier coating than the steel pipe.

I want to speak a little bit from the standpoint of whether the pretty widespread faith in wrought iron is justified, and why should wrought iron get any black eye at all? I think it is a pretty unanimous opinion that pipe which was made fifty or forty or thirty years ago has set a standard which we are all striving to reach to-day. The steel man sets that up as a standard towards which he is striving in the manufacture of his material. There seems to be no question about that old-time material and its quality.

I wish to speak very briefly with regard to the protective influence of slag, because I really and firmly believe, after a number of years' study of the corrosion problem, that much of the merit which wrought iron has in comparison with steel is due to the slag which is present in the former. Both products are the result of the refining of crude pig iron, and both of them during the refining have slags formed which are silicates of iron, materials of a glassy nature. Steel in the finished product has none of this slag, because in the finishing operation the material is fluid, and consequently any slag floats to the surface and comes off.

In the manufacture of wrought iron, on the other hand, the furnace-finishing temperatures are not high enough to have the metal in a fluid condition; consequently, the slag is trapped in the metal, about the same as water would be held in a sponge. Just as you can't get all of the water out of a sponge by squeezing, so you can't get all of this slag out of the puddle ball. This slag is an iron silicate which, so far as its corrosive nature is concerned, is immune from attack under ordinary conditions. The amount of

the slag is about two per cent. by weight, or, to put it in a little better fashion, it is probably six per cent. by volume. The contention is generally made by those who oppose wrought iron that that quantity of slag is altogether too small to offer any resistance or obstruction to corrosive attack. Now, I combat that contention. The effectiveness of any barrier does not depend entirely on its quantity, but it depends upon its manner of distribution. The slag which exists in wrought iron is originally in small globules, which, under the forces that are exerted in the rolls, are elongated into threads, or better, and more generally, in the form of ribbons, in which the lengthwise direction corresponds to the length of the pipe, the width corresponds to the circumference of the pipe, and the thickness corresponds to the thickness of the pipe. By actual count, the number of these slag filaments is from four hundred thousand or five hundred thousand to probably a million per square inch. In other words, they are probably not over one five-hundredth to one one-thousandth of an inch apart in the width of material, and about the same distance apart in the thickness of the metal. Ideally, they are scattered in a uniform distribution.

What is the effect of that slag in retarding corrosion? There is a lessened surface, probably six per cent. of lessened surface to the corrosive attack. Second, as the attack proceeds, it is the iron which is going to be corroded. As the result, iron oxide or iron hydrate will be formed, which we call rust. But it has to stop, for as soon as this corrosion penetrates a short distance, it will strike one of the slag barriers, and the more the iron tends to corrode away, the more and more of these inert slag barriers it exposes to the attack. We also have, of course, the obstruction of the lengthened path through the material because of the barrier action. It might be said that the argument is rather far-fetched, yet we grant that very thing is the mechanism by which cast iron owes whatever it has of resistance to corrosion, only in the case of cast iron it is graphite that is distributed in the form of little flakes. As the iron corrodes, more and more of these graphite flakes are brought to the surface by the very nature of corrosion, and consequently offer a surface which is of greater and greater resistance, and more immune from attack, as the corrosion proceeds.

Uniform distribution of slag has the additional advantage also, that, if this surface barrier is abraded or taken away by any means, it automatically renews itself. I believe the slag content is the reason why wrought iron has more resistance to corrosive attacks, exceeding that of a material which does not have the barrier obstruction.

MR. SPELLER. If I might answer a few of the points raised by Mr. Aston, I would emphasize again that the accumulation of service tests, the results of which neither the manufacturers of wrought iron nor any other party have contested, were obtained not on three or four pieces but on hundreds of pieces of presumably the best wrought iron on the market. Good wrought iron has not been clearly defined, but the brand which Mr. Aston so ably advocates was well represented in these tests. Analyses were made, also many microscopic examinations, without any evidence that the amount of cinder or the way it was scattered through the iron had any bearing on the results. If all those who have made such comparative tests have been so unfortunate as to have picked out inferior iron, as Mr. Aston claims, there must be a larger proportion of this on the market of all brands than we would have supposed possible. I do not advocate the use of a mixture of steel scrap in wrought iron, believing that it is better to make pipe of the proper grade of steel throughout; but no evidence has yet been produced, so far as we know, to prove that wrought iron so made is inferior in lasting qualities, and it would be a very easy matter to make such tests. Mr. Aston has spent a lot of time explaining why wrought iron *should* be more lasting than steel on account of the impurities in the form of cinder which it carries. The same argument might obviously be used to prove why it should corrode faster than steel, which is almost free from such foreign matter, for this cinder is, like copper, electro-negative to iron and thus tends to accelerate corrosion locally. Moreover, the cinder is very irregularly distributed and hence does not compare in any way with the graphite in cast iron, to use the comparison made by Mr. Aston. However, theories will not make wrought-iron pipe last longer, and the indisputable facts of experience on the part of hundreds of observers who have had experience with both materials indicates that the assumed difference, which Mr. Aston labors to explain, in fact does not exist.

A few years ago, at one of your meetings (JOURNAL New England Water Works Association, XXVI), Dr. W. H. Walker, director of Research Laboratories, Massachusetts Institute of Technology, referred to "sixty-four comparisons of iron and steel pipe where the history of the installation was known [all taken from service lines in the vicinity of Boston]. The results showed:

Iron more corroded than steel	20
Steel more corroded than iron	18
Iron and steel equally corroded	9
Corrosion negligible	17

"These results again demonstrate that, taken on the average, there is no difference in the corrosion of iron and steel pipe. Conversations held with the engineers in charge of plants during this investigation confirm the statement already made that a pipe is frequently called steel when corrosion is found to be excessive, while it is set down as iron if it rusts but little."

It appears, from this discussion, that, while in New England, as elsewhere, water conditions have much to do with life of service lines, lead, lead-lined, or cement-lined pipe has given satisfactory service so far as internal corrosion is concerned. Steel pipe is free from blisters, and particularly adapted for lining. By providing adequate protection for the outside where necessary, in the form of bituminous soaked fabric or cement casing, according to the character of the soil, it would appear possible to make a wrought service line last as long as desired. The outside and inside protection of iron and steel pipe are two separate problems each requiring special treatment. The Standard Oil Companies have had many steel lines in service twenty years or more in salt marshes and in soil saturated with acid mine water where the pipe is protected by a 2-in. casing of concrete. Such protection might be easily applied where the services pass through foundations, which appears to be a favorite place for corrosion.

MR. ASTON. In answer to Mr. Speller's remarks regarding slag distribution in wrought iron, the more we depart from the exceedingly fine and uniform distribution which was cited in my discussion, the more we digress from the ideal product or from well-made wrought iron; and if any area the size of an average

pit fails to have a multitude of the slag filaments, the product is certainly not a well-puddled wrought iron.

Cinder may tend to promote galvanic action. The potential in conjunction with iron is no doubt, however, rather low. But of greater importance is the quantity of electrical current flow, since the rate of corrosion is proportional to this current. With a certain potential difference, current magnitude depends upon the resistance of the circuit, and since the slag has a very high resistance, the corrosion current is reduced to a relatively small quantity. Furthermore, whatever may be its magnitude, the very corrosion of the iron exposes more and more of the slag barriers; the more rapid the initial corrosion, the sooner the slag becomes the protective surface.

Mr. Speller — and this criticism applies to many citations of tests — compares the qualities of wrought iron and steel on the basis of chemical analyses. I tried to make clear the fact that slag distribution, more than quantity, is the important consideration. Composition depends upon the sampling — quantity and location — and is at best only an average of the quantity of material selected. The more heterogeneous the material, the more the sample is likely to vary from the extremes of composition in the different areas. I have found many examples of so-called wrought iron, poorly made or badly adulterated with steel, which on the face of chemical analyses had all the earmarks of a good product.

MR. SPELLER. I would again point out the entire lack of any evidence from service tests as to the protection afforded by cinder in puddled iron. Even if this had been proved, how is any one going to determine whether this cinder is finely distributed, as Mr. Aston says is necessary to accomplish the desired object? If, as he asserts, the hundreds of comparisons of iron and steel pipe from service represent poor wrought iron, the need of some practical means for detecting such iron is very evident.

RAPID SAND FILTRATION.

BY GEORGE A. JOHNSON, CONSULTING HYDRAULIC ENGINEER AND SANITARY EXPERT, NEW YORK CITY.

[*Read September 12, 1917.*]

FOREWORD.

The subject of this essay, suggested to the author by President Saville, is "Rapid Sand Filtration," an art in the science of water purification first applied in the treatment of municipal water supplies in the year 1885. Up to that time it had been used only in the purification of waters for industrial uses, while slow sand filtration had already gained an accredited standing abroad as a potent aid in the reduction of water-borne diseases. When the rapid sand filter first entered the field of municipal water purification, in 1885, a few small slow sand filter plants had been built in this country, the first of these being at Poughkeepsie and Hudson, N. Y.

The first municipal water filter of the rapid sand type was built at Somerville, N. J., and thus began its wonderful history. From its very inception it established its popularity over all other hitherto attempted methods of purifying water, and has steadfastly held that position throughout the thirty-two years which have since elapsed.

It is not the intention or desire of the author to encroach unduly on the subject of slow sand filtration, which is to be discussed by Mr. Goodnough. He deems it necessary, however, to refer briefly to the use of that process of water filtration in America, and to present certain statistical data for comparison with similar figures for rapid sand filters.

WATER FILTRATION AND DISEASE PREVENTION.

Twenty-seven years ago, when the art of water filtration was in its infancy in this country, 32 000 residents of continental United States succumbed each year to typhoid fever. This was a death-

rate of about 50 per 100 000 population. To-day, with municipal water filtration plants in operation in 736 communities having a total population of 18 293 000, the number of typhoid fever deaths is about 13 000 annually, corresponding to a death-rate of 13 per 100 000 population living. If the typhoid fever death-rate of twenty-seven years ago existed now, some 750 000 people would suffer from it and 51 000 people would die of the disease in a single year. Since 1890, therefore, because of the public acceptance of lower standards of sanitation than exist to-day, 847 000 people died of typhoid fever in the United States, and easily 10 000 000 suffered from it but recovered.

These figures present a sinister economic aspect. Each death from typhoid fever represents an economic loss to the country of $7 500.* Accordingly, in the past twenty-seven years, due to ignorance and faulty sanitation, the huge sum total of $6 352 500-000 has been dissipated through sickness and death from typhoid fever in the United States. This sum is twice the interest on the total debt so far incurred by all the nations actively involved in the Great War. It is twenty times the property loss in the greatest conflagration of all time, the San Francisco fire of 1906. It would build 200 000 miles of the best bituminous-macadam roads, and is equal to two thirds of all the money on deposit in United States national and savings banks.

The present generation has seen great advances in numerous branches of municipal sanitation other than the purification of public water supplies. Unquestionably some of these have been potent factors in the diminution of typhoid fever in America, and while it is not the author's intent to attribute to purer water the entire credit for this improvement, he believes the facts prove that the substitution of pure for polluted water supplies was by long odds the most important cause contributing to this end. A fair argument for this viewpoint is found in Table 1.

The figures shown in Table 1 are very suggestive. When the ratio of population supplied with filtered water to total urban population in the United States increased from 1 in 80 to 1 in 18 in the decade 1890–1900, the urban typhoid fever death-rate

* "The Typhoid Toll." *Journal American Water Works Association*, Vol. 3, No. 2, p. 254, June, 1916.

TABLE 1.

TYPHOID FEVER DEATH-RATES AND POPULATIONS SUPPLIED WITH FILTERED WATER.

Year.	Estimated Urban Population of the United States.	Total Population Supplied with Filtered Water.	Proportion of Filtered Water Population to Total Urban Population.	Typhoid Fever Death-Rate per 100 000 Population in Urban United States.
1890	25 000 000	310 000	1 in 80	48
1900	34 000 000	1 860 000	1 in 18	40
1910	44 000 000	10 805 000	1 in 4	27
1917	51 000 000	18 293 000	1 in 3	13

decreased 17 per cent. When this ratio again increased from 1 in 18 to 1 in 4 in the decade 1900–1910, the typhoid fever death-rate showed a decrease of 32 per cent. in the same period; and when the ratio of " filtered water population " to total urban population again increased from 1 in 4 to 1 in 3 in the six-year period ending in 1917, the urban typhoid fever death-rate fell 52 per cent. The relationship between the increasing number of people receiving filtered water and the decrease in the typhoid fever death-rate is too positive to permit the dismissal of the phenomenon on the grounds of mere coincidence.

There is another feature in connection with disease reduction by water filtration to which attention must be called, and that is, that where one death from typhoid fever has been avoided by the use of better water, a certain number of deaths, probably two or three, from other causes have been avoided. This is known as Hazen's theorem. The records from fifteen representative cities * bear out this assumption in a striking manner, as follows:

TABLE 2.

DEATH-RATES FROM ALL CAUSES AND FROM TYPHOID FEVER IN CITIES BEFORE AND AFTER FILTRATION.

Per 100 000 Population.	Before Filtration.	After Filtration.
Total death-rate	1 870	1 730
Typhoid fever death-rate	67	25
Typhoid lives saved	—	42
Other lives saved	—	98

* " Present-Day Water Filtration Practice." *Journal American Water Works Association*, Vol. 1, No. 3, p. 516, 1914.

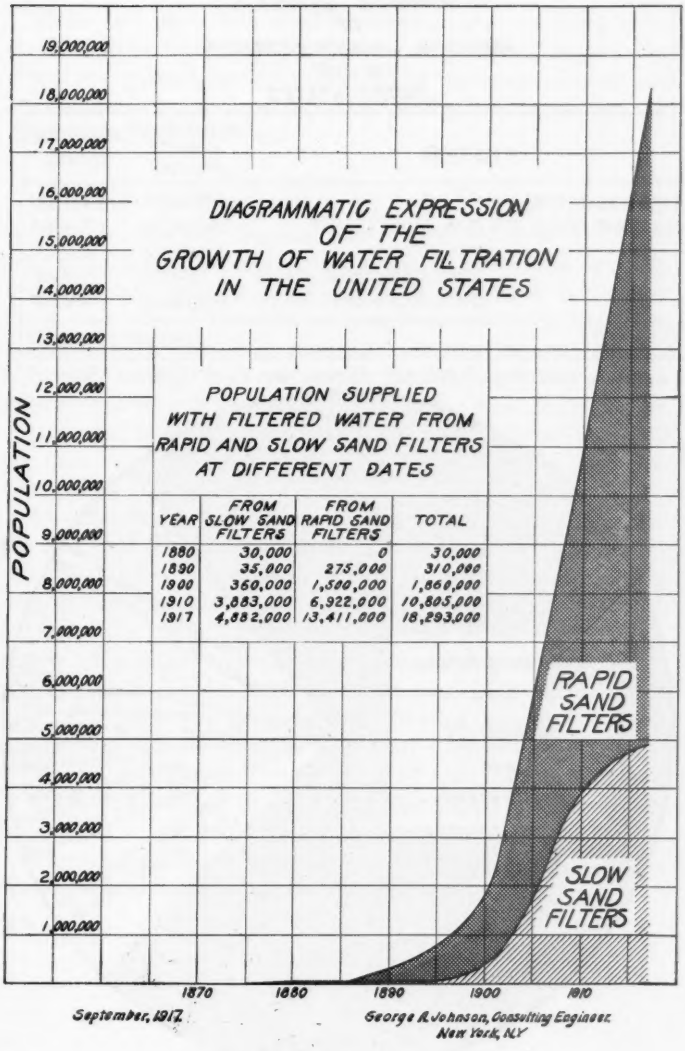

DIAGRAMMATIC EXPRESSION
OF THE
GROWTH OF WATER FILTRATION
IN THE UNITED STATES
POPULATION SUPPLIED
WITH FILTERED WATER FROM
RAPID AND SLOW SAND FILTERS
AT DIFFERENT DATES
YEAR | FROM SLOW SAND FILTERS | FROM RAPID SAND FILTERS | TOTAL
1880 | 30,000 | 0 | 30,000
1890 | 35,000 | 275,000 | 310,000
1900 | 360,000 | 1,500,000 | 1,860,000
1910 | 3,883,000 | 6,922,000 | 10,805,000
1917 | 4,882,000 | 13,411,000 | 18,293,000
POPULATION
19,000,000
18,000,000
17,000,000
16,000,000
15,000,000
14,000,000
13,000,000
12,000,000
11,000,000
10,000,000
9,000,000
8,000,000
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
1870
1880
1890
1900
1910
RAPID SAND FILTERS
SLOW SAND FILTERS
September, 1917.
George A. Johnson, Consulting Engineer.
New York, N.Y.

FIG. 1.

DIAGRAMMATIC EXPRESSION OF MUNICIPAL WATER FILTRATION IN THE UNITED STATES

SYSTEM	DAILY FILTERING CAPACITY (GALLONS)	POPULATION SERVED
RAPID SAND FILTERS	2,388,000,000	13,411,000
SLOW SAND FILTERS WITH PLAIN SEDIMENTATION	196,000,000	1,221,000
" " " " PRE-FILTRATION	218,000,000	807,000
" " " " COAGULATION & SEDIMENTATION	115,000,000	874,000
" " " " COAGULATION & PRE-FILTRATION	393,000,000	1,980,000
ALL KINDS	3,310,000,000	18,293,000

Diagram Indicates Population Served by Each Type of Filter

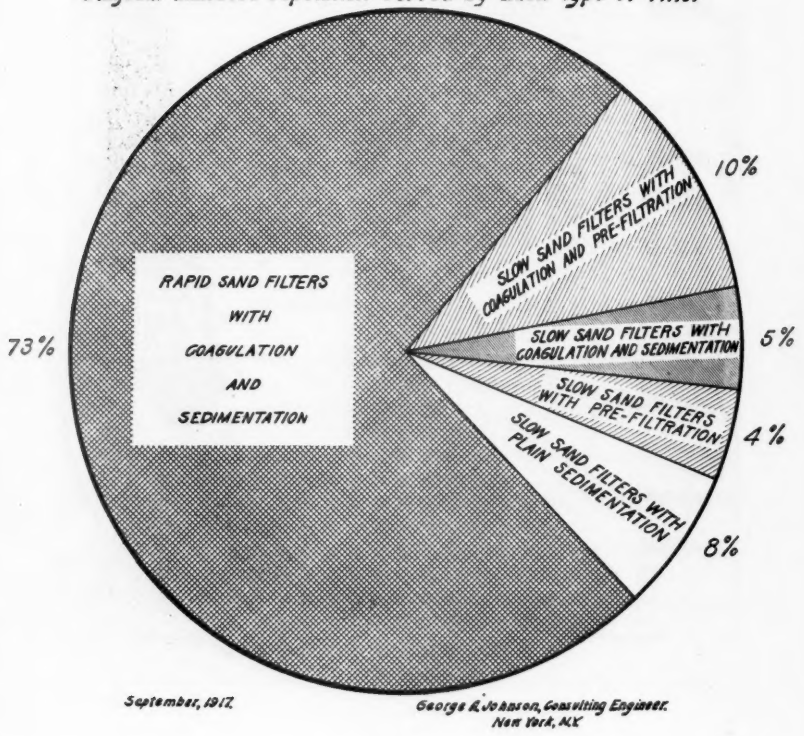


FIG. 2.

These data show with much positiveness the soundness of the so-called Hazen's theorem, and prove in a striking manner that where one typhoid death was avoided by the substitution of pure for impure water, at least two other deaths from causes less well defined were also prevented.

Growth of Water Filtration in North America.

The accompanying diagram, Fig. 1, shows the growth of filtration of municipal water supplies in the United States since the first filter was built at Poughkeepsie in 1874, some forty-three years ago. One of the most striking features of this diagram is the positiveness with which rapid sand filtration has outgrown the older slow sand method. Of the 18 293 000 people now supplied with filtered water in the United States, 73 per cent., or 13 411 000, are supplied from 682 rapid sand filter plants, the remaining 27 per cent., or 4 882 000 people, being served from 54 slow sand filter plants. (See Fig. 2.)

Once the rapid sand process appeared in the field it assumed the lead, and has steadily forged still further ahead. The same thing is also true in Canada. In the Dominion, there are now some 45 municipal filter plants supplying a total of about 1 500 000 people, or about one in every six of the total population. Thirty-nine of these plants are rapid sand filters serving about 1 000 000 people. In foreign countries, there are some 81 municipal rapid sand filter plants with a total daily filtering capacity of about 175 000 000 U. S. gal., and serving about 3 500 000 people.

Detailed tabulations of rapid and slow sand filter installations in North America, and of rapid sand filter plants in foreign countries, are to be found in Tables 7 to 11.

Summarizing, the following shows the existing status of water filtration so far as the available data will allow:

TABLE 3.

STATUS OF MUNICIPAL WATER FILTRATION IN NORTH AMERICA.

January, 1917.		United States.	Canada.	Totals.
Number of places.	Rapid sand	682	39	721
	Slow sand	54	6	60
	Total	736	45	781
Total population served.	Rapid sand	13 411 000	1 000 000	14 411 000
	Slow sand	4 882 000	500 000	5 382 000
	Total	18 293 000	1 500 000	19 793 000
Proportion of "filtered water population" to total population.	Rapid sand	1 : 7.6	1 : 9	1 : 7.7
	Slow sand	1 : 20.9	1 : 18	1 : 20.6
	Total	1 : 5.6	1 : 6	1 : 5.6

Since 1910, the progress in municipal water filtration in the United States has been noteworthy. The population supplied with filtered water has increased 69 per cent., and the total capacity of the filter plants in operation has increased 81 per cent. The increase in rapid sand filtration has been particularly marked in the last six years, the population served by filters of this type having increased by 94 per cent., as compared with an increase of 26 per cent. for slow sand filters. The daily filtering capacity of slow sand filter plants has increased by 11 per cent. since 1910, whereas the capacity of rapid sand filter plants has shown an increase of 139 per cent. This is explainable by the fact that the increase in the population served by slow sand filters is accounted for chiefly by the natural increase in population in cities which already had filter plants in 1910, but few new slow sand filter plants having been built since that time. The increase in population served by rapid sand filters since 1910, however, was principally due to the construction of new filter plants, as, for example, those built at Akron, Ohio; Baltimore, Md.; Dallas, Tex.; Erie, Pa.; Grand Rapids, Mich.; Minneapolis, Minn.; St. Louis, Mo.; and Trenton, N. J. These eight plants alone provided a filtering capacity of 462 000 000 gal. daily, and serve a total present population of 2 400 000.

Since 1910, the most notable additions to the slow sand filters in operation are the plants at Brookline and Lowell, Mass., and the Queen Lane plant at Philadelphia. The two Massachusetts

plants were built especially with iron and manganese removal in view. One large slow sand plant, that at Wilmington, Del., is now being supplemented by a rapid sand plant of modern design.

TABLE 4.

INCREASE IN MUNICIPAL WATER FILTRATION IN THE UNITED STATES SINCE THE YEAR 1910.

(January, 1917.)

	Year.	Rapid Sand Filters.	Slow Sand Filters.	Total.
Population served	1910	6 922 000	3 883 000	10 805 000
	1917	13 411 000	4 882 000	18 293 000
Per cent. increase.....	....	94	26	69
Daily filtering capacity (gallons)	1910	1 000 000 000	830 000 000	1 830 000 000
	1917	2 388 400 000	921 900 000	3 310 300 000
Per cent. increase.....	....	139	11	81

MODIFIED USE OF SLOW SAND FILTERS.

A noteworthy feature in connection with slow sand filtration practice in America is that alterations have been made in the lay-outs originally designed for several large cities, with the adoption of either pre-filtration, or coagulation, or both, in the pre-treatment of the water before final filtration through the slow sand filters. Thus at Albany, coagulating basins and preliminary roughing filters have been added to the original slow sand filter plant to lessen the load on the final filters and permit them to do satisfactory work. For the same reason, preliminary filters were added to the Pittsburgh plant two years after the original plant went into operation. Philadelphia has adopted coagulation of the raw water at four out of five plants, and at Washington and Poughkeepsie, coagulation of the raw water now forms a part of the preparatory treatment.

Of the forty cities wherein the slow sand filters are operated as such without radical modifications, those of Denver, New Haven, Yonkers, Reading, Providence, and Philadelphia (Upper Roxborough) are the largest, and have a combined daily capacity of 124 000 000 gal. The remaining thirty-five plants are small, averaging a daily capacity of 2 000 000 gal.

Of the fifty-four cities having slow sand filter plants now in service in the United States, with a total daily filtering capacity of 922 000 000 gal., forty provide no pre-treatment other than plain sedimentation in impounding reservoirs or settling basins. The plants in these forty cities have a total rated daily capacity of 196 000 000 gal., or an average of 4 900 000 gal. daily.

The remaining fourteen cities have slow sand plants with a total filtering capacity rated at 726 000 000 gal. In five of these cities, slow sand filtration is preceded by pre-filtration at high rate; in four cities, by coagulation and pre-filtration; in one city (Philadelphia), by coagulation and pre-filtration at four plants; and in the remaining five cities by coagulation and sedimentation.

TABLE 5.

PREPARATORY TREATMENT OF WATER PRIOR TO SLOW SAND FILTRATION.

Number of Cities.	Kind of Preparatory Treatment.	Total Daily Filtering Capacity. Gallons.	Per Cent. of Total.
40*	None, other than plain sedimentation in impounding reservoirs or settling basins.	196 000 000	21.3
4*	Coagulation and pre-filtration.	393 000 000	42.7
5	Coagulation and sedimentation.	115 000 000	12.4
6	Pre-filtration only.	218 000 000	23.6

STATISTICS OF GEOGRAPHICAL GROUPING OF MUNICIPAL FILTERS.

One third of the total population of the United States supplied with filtered water is located in the Middle Atlantic District, comprising the states of New York, New Jersey, and Pennsylvania. The urban population in this district is proportionately large,† however, when compared with similar figures for other districts. This fact, and the big slow sand filter plants at Albany, N. Y.,

* Philadelphia counted twice, since coagulants are not used at all five plants.

† Ratio of urban population to total population in the state:

	Per Cent.
New York	74.3
New Jersey	64.5
Pennsylvania	47.7
The three states	62.4

Philadelphia, Pittsburgh, and Reading, Pa., and the large rapid sand filter plants at Binghamton and Niagara Falls, N. Y., Little Falls, New Milford, and Trenton, N. J., Erie, Harrisburg, and South Pittsburgh, Pa., in a material fashion served to increase far above the average the ratio of population provided with filtered water to total population. Elsewhere in the country it is quite noteworthy how remarkably proportionate is the subdivision of the population receiving filtered water with the subdivision of the population of the country by districts.

TABLE 6.

SLOW SAND FILTER PLANTS IN THE UNITED STATES.

(January, 1917.)

State.	Number of Places.	Total Population Served. (Estimated.)	Total Daily Filtering Capacity. (Gallons.)
Arizona	1	4 000	300 000
Colorado	4	150 000	42 500 000
Connecticut	4	141 000	25 000 000
Delaware	1	102 000	12 000 000
District of Columbia	1	389 000	75 000 000
Indiana	1	333 000	20 000 000
Maine	1	15 000	4 000 000
Massachusetts	8	396 000	40 300 000
New Hampshire	3	30 000	4 000 000
New Jersey	1	2 000	200 000
New York	13	348 000	57 200 000
North Carolina	1	2 000	300 000
Pennsylvania	8	2 620 000	607 000 000
Rhode Island	1	263 000	18 000 000
South Dakota	1	3 000	400 000
Texas	1	12 000	1 000 000
Vermont	1	9 000	2 500 000
Wisconsin	3	63 000	12 200 000

In Tables 7 to 11 inclusive, statistics covering the number of rapid and slow sand filter plants, population served, and capacity of works, are given by states and geographical groupings.

In the New England District, 24 per cent. of the total urban population are supplied with filtered water, and in the past ten years the filter capacity has increased by 58 per cent.

In view of the relatively greater congestion of the population in New York, New Jersey, and Pennsylvania, it is by no means remarkable that the Middle Atlantic District stands at the head of all the districts in the use of filtered water. The pollution of the rivers and lakes from which the bulk of the community centers of this district draw their water supplies is steadily increasing, and filtration is recognized as an absolutely necessary measure of protection. In fact, there are but seven cities in the district having populations in excess of 100 000 where filtration of the water supply is not practiced, namely, New York, Buffalo, Camden, Jersey City, Newark, Rochester, and Syracuse. In a number of these cities, filtration is being agitated, and for years has been considered advisable. Doubtless at the close of the present decade, at least two and probably more of these cities will have adopted filtration. It is noteworthy that in this district, on the basis of population served, municipal water filtration has increased by practically 100 per cent. in the past six years.

In the South Atlantic, East North Central, and West North Central districts, 40.5, 32.0, and 35.9 per cent. respectively of the urban population are now supplied with filtered water. Particularly marked increases during the past ten years in Maryland, Ohio, Illinois, Minnesota, Michigan, Missouri, and Kansas are largely responsible for the present showing.

In the East South Central District, 20.2 per cent. of the urban population is supplied with filtered water, the relatively small increase in filter capacity in this district in recent years having been largely due to some additions in Kentucky. The lack of activity along water filtration lines in this district is worthy of mention and hard to explain, for the typhoid record of the district is far from good. Kentucky, for example, the only state in the district from which entirely reliable mortality statistics are available, has an annual typhoid fever death-rate nearly three times the average for all the registration states, with a population of over 60 000 000.

In the West South Central District, 25.2 per cent. of the urban population is supplied with filtered water. Advances in Texas played the most important part in the increased filter capacity in this district during the last decade.

In the Mountain and Pacific districts, 23.7 and 18.0 per cent. respectively of the urban population are supplied with filtered water. Large numbers of the public supplies continue to be taken from mountain streams and lakes.

TABLE 7.

LIST OF SLOW SAND FILTER PLANTS IN OPERATION IN THE UNITED STATES.

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
ARIZONA.			
Yuma	2 910	1903	0.3
COLORADO.			
Buena Vista	1 040	——	0.5
Canon City	5 160	1908	2.0
Denver	113 400	1890	35.0
Greeley	8 180	1906	5.0
CONNECTICUT.			
Bethel	3 790	——	0.5
New Haven	100 000	1905	20.0
Putnam	7 280	——	2.0
South Norwalk	8 970	1907	2.5
DELAWARE.			
Wilmington	87 400	1909	12.0
DISTRICT OF COLUMBIA.			
Washington	331 100	1905	75.0
INDIANA.			
Indianapolis	282 900	1903	20.0
MAINE.			
Augusta	13 210	1914	4.0
MASSACHUSETTS.			
Brookline	27 800	1915	5.0
Greenfield	10 430	——	1.0
Lawrence	85 890	1893–1907	6.0
Lowell	106 290	1915	10.0
Marblehead	7 340	1908	2.0
Marion	1 000	——	0.3
Middleboro	8 210	1913	1.0
Springfield	88 930	1906	15.0

TABLE 7. — *Continued.*

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
NEW HAMPSHIRE.			
Dover	13 250	1902	2.0
Franklin	6 130	——	0.5
Somersworth	6 700	1897	1.5
NEW JERSEY.			
Matawan	1 650	——	0.2
NEW YORK.			
Albany	100 250	1899	25.0
Brooklyn	10 000	1909	1.0
Deposit	1 860	——	0.5
Geneva	12 450	1911	3.0
Hudson	11 420	1876	2.5
Ilion	6 590	——	1.2
Mechanicville	6 630	——	2.0
Nyack	4 620	1899	2.0
Ogdensburg	15 930	1912	3.0
Peekskill	15 240	1909	3.0
Poughkeepsie	27 940	1874	3.0
Westfield	2 990	——	1.0
Yonkers	79 800	1906	10.0
NORTH CAROLINA.			
Marion	1 520	——	0.3
PENNSYLVANIA.			
Apollo	3 010	——	2.0
Berwin	1 000	1898	2.0
Coatesville	11 080	1915	2.0
Philadelphia	1 549 000	1902	368.0
Pittsburgh	533 900	1908	200.0
Reading	96 070	1903–1915	25.0
South Bethlehem	19 970	1904	4.0
Steelton	14 250	1907	4.0
RHODE ISLAND.			
Providence	224 330	1904	18.0
SOUTH DAKOTA.			
Hot Springs	2 140	——	0.4

TABLE 7. — *Concluded.*

City.	1910 Population.	Date Installed.	Capacity (M.G.D.)
TEXAS.			
San Angelo	10 320	——	1.0
VERMONT.			
St. Johnsbury	8 100	1897	2.5
WISCONSIN.			
Ashland	11 590	1895	2.0
Mellen	1 830	——	0.2
Superior	40 380	1899	10.0

TABLE 8.

RAPID SAND FILTER PLANTS IN THE UNITED STATES.

(January, 1917.)

State.	Number of Places.	Total Population Served. (Estimated.)	Total Daily Filtering Capacity. (Gallons.)
Alabama	13	255 000	33 400 000
Arkansas	9	107 000	16 100 000
California	16	370 000	36 300 000
Colorado	4	129 000	24 900 000
Connecticut	5	29 000	6 200 000
Delaware	1	102 000	12 000 000
Georgia	29	511 000	66 500 000
Iowa	21	304 000	41 700 000
Indiana	18	343 000	63 000 000
Illinois	36	507 000	111 100 000
Kansas	32	298 000	43 600 000
Kentucky	19	480 000	114 000 000
Louisiana	4	473 000	52 500 000
Maine	8	75 000	20 300 000
Maryland	10	723 000	145 900 000
Massachusetts	4	22 000	4 700 000
Michigan	10	263 000	53 400 000
Minnesota	11	465 000	67 100 000
Missouri	31	1 165 000	208 400 000
Mississippi	5	67 000	13 300 000

TABLE 8. — *Continued.*

State.	Number of Places.	Total Population Served. (Estimated.)	Total Daily Filtering Capacity. (Gallons.)
Montana	6	38 000	22 800 000
Nebraska	1	6 000	400 000
New Hampshire	3	26 000	2 700 000
New Jersey	31	1 286 000	179 200 000
New Mexico	1	5 000	1 500 000
New York	50	558 000	142 100 000
North Carolina	38	347 000	45 600 000
North Dakota	6	46 000	8 800 000
Ohio	46	1 560 000	324 900 000
Oklahoma	25	228 000	40 400 000
Oregon	10	36 000	12 400 000
Pennsylvania	90	1 266 000	283 200 000
Rhode Island	5	73 000	13 500 000
South Carolina	15	186 000	23 800 000
South Dakota	1	6 000	1 500 000
Tennessee	8	128 000	24 500 000
Texas	18	395 000	41 300 000
Vermont	2	27 000	2 600 000
Virginia	14	227 000	28 600 000
Washington	2	9 000	1 500 000
West Virginia	13	127 000	22 100 000
Wisconsin	7	128 000	24 500 000
Wyoming	4	15 000	6 100 000

TABLE 9.

LIST OF RAPID SAND FILTER PLANTS IN OPERATION IN AMERICA.

(January, 1917.)

[NOTE. — (P) represents pressure filters.]

ALABAMA.

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Birmingham	166 150	1906	20.0
Bessemer	———	1916	0.1
Cordova	1 750	——	0.3
Decatur	4 230	1910	2.5
Eufaula (P)	4 260	1907	0.5
Flat Top	500	1916	0.1
Florence	6 690	1916	1.5

TABLE 9. — *Continued.*

ALABAMA. — *Continued.*

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Gadsden	10 560	1910	2.0
Montgomery	——	——	1.0
New Decatur	6 100	1911	2.5
Opelika	4 730	——	0.7
Pratts	2 000	1913	0.2
Tuscaloosa	9 820	1914	2.0
ARKANSAS.			
Arkadelphia (P)	2 750	1915	0.6
Conway (P)	2 790	1910	0.5
Eureka Springs	3 230	1914	0.8
Fort Smith	23 970	1913	3.0
Little Rock (P)	45 940	1891–1897	8.5
Luxora	1 000	1914	0.3
Morrilltown (P)	2 420	1912	0.4
Newport (P)	3 560	1910	0.5
Texarkana	5 660	——	1.5
CALIFORNIA.			
Antioch (P)	1 120	1915	0.7
Black Diamond (P)	2 370	1909	0.7
Cherry Canon (P)	1 000	1912	0.2
Eureka (P)	13 770	1912	1.5
Fort Baker (P)	500	1912	0.1
Merced Falls (P)	500	1912	0.1
Oakland (P)	219 650	1891	7.0
Portersville (P)	2 700	1891	0.2
Presidio (P)	1 000	1911	1.0
Rio Vista	500	——	0.4
Riverside (P)	18 300	1892	0.1
San Diego (P)	48 620	1906–1915	10.0
San Francisco (P)	———	1912	12.5
Scotia	700	1913	0.1
Spring Valley (P)	———	1912	1.0
Watsonville	4 450	1908	0.7
COLORADO.			
Berthoud	1 000	1907	0.7
Denver	100 000	1890	20.0
Fort Collins	8 200	1910	4.0
Sugar City	1 100	1907	0.2

TABLE 9. — *Continued.*

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
CONNECTICUT.			
Bethel	1 900	——	0.5
Collinsville (P)	3 000	1916	0.2
Greenwich (P.)	16 460	1887–1909	3.5
New Canaan (P)	3 670	1913	1.0
Norwich (P)	——	1911	1.0
DELAWARE.			
Wilmington	87 400	1916	12.0
GEORGIA.			
Athens	14 900	1909–1912	5.0
Atlanta (P)	224 460	1887–1910	21.0
Augusta	47 740	1889–1912	9.0
Carrollton	3 300	1905	0.5
Cartersville	4 070	1912	1.0
Columbus	20 550	1903–1912	6.0
Commerce	2 240	——	0.3
Covington	2 700	——	0.7
Cuthbert	3 210	1910	0.5
Dalton	5 320	1908	0.5
Decatur	2 470	1912	1.0
Eatonton	2 040	1897	0.3
Elberton	6 480	1904	0.5
Gainesville	5 920	1911	1.0
Jackson	1 860	——	0.4
Jefferson	1 210	1915	0.3
La Grange	5 590	——	1.5
Macon	40 660	1898–1916	8.0
Madison	2 410	1907	0.4
Marietta	5 950	1908	1.0
Milledgeville	4 380	1910	1.0
Milledgeville (Hospital)	——	1893	0.5
Monroe	3 030	1905	0.5
Perry	1 000	——	0.7
Rome	14 400	1908–1912	3.0
Tallapoosa	2 120	——	0.3
Thomaston	1 640	1912	0.5
Toccoa	3 120	——	0.1
West Point	1 910	1902	1.0

TABLE 9. — *Continued.*

ILLINOIS.

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Alton	17 530	1906–1915	4.0
Cairo	14 550	1910	4.0
Carlinville	3 620	1907	1.0
Champaign	12 420	1912	2.0
Charleston	5 880	1912	1.0
Chicago Stock Yards	———	1908	5.0
Danville	27 870	1903–1910	3.7
Decatur	31 140	1914	9.0
East St. Louis (P)	58 550	1900	17.0
Elgin (P)	25 980	1898	3.5
Evanston	24 980	1914	12.0
Freeport	17 570	1903–1913	4.0
Fort Sheridan (P)	1 800	1912	2.0
Hamilton	1 630	1912	1.0
Harrisburg	5 300	1914	0.9
Herrin	6 860	1915	1.0
Hinsdale	2 450	1914	1.0
Kankakee	17 170	1905–1907	4.0
Kenilworth (P)	500	1907–1909	1.6
Lake Forest (P)	3 350	1892	1.0
Lawrenceville	3 230	1913	0.7
McLeansboro (P)	1 800	1912	0.2
Macomb	5 780	1913	1.0
Moline	24 200	1903–1913	5.7
Mt. Carmel	6 930	1910	1.0
Mt. Vernon	8 010	1913	1.5
Murphysboro	7 480	1915	2.2
Pana	6 060	1911	1.0
Pontiac	6 090	1898	1.5
Quincy	36 590	1914	6.0
Rock Island	24 300	1910	6.0
Rock Island(Arsenal)	2 000	1912	1.5
Rogers Park (P)	1 000	1889–1906	0.9
Sparta	3 080	1915	0.5
Streator	14 250	1889	2.5
Warsaw	2 250	1912	0.2

TABLE 9. — *Continued.*

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
INDIANA.			
Anderson	22 480	1904–1916	5.0
Aurora	4 410	1904	1.0
Columbus	8 810	1912	4.0
Evansville	71 280	1910	12.0
Jasper (P)	2 200	1916	1.0
Logansport	19 050	1913	8.0
Mount Vernon	5 560	1913	2.0
Muncie (P)	24 000	——	4.0
New Albany	20 630	1916	4.0
Paoli (P)	1 280	1916	0.5
Princeton	6 450	1915	3.0
Seymour	6 300	1905	2.0
Terre Haute (P)	64 600	1890–1900	9.0
Valparaiso	6 990	1907	2.0
Vincennes	14 900	1890	2.0
Warsaw	4 430	1896	0.5
Washington	7 850	1906	2.0
West Baden (P)	1 000	1907	1.0
IOWA.			
Ames	4 220	1915	0.9
Burlington	24 320	1905	5.0
Cedar Rapids	32 810	1912	4.0
Centerville (P)	6 940	1913–1916	0.7
Chariton (P)	3 790	1916	0.5
Clear Lake (P)	2 010	——	0.4
Clinton (P)	25 580	1899	1.0
Creston	6 920	1893	1.0
Davenport (P)	43 030	1891–1908	9.0
Fairfield	4 970	1911	1.0
Fort Madison	8 900	1916	3.0
Indianola	3 280	1905	0.5
Iowa City	10 090	1909	2.0
Keokuk (P)	14 010	1893	3.5
Lenox (P)	1 270	1914	0.2
Oskaloosa (P)	9 470	1902	1.3
Mount Pleasant	3 870	1888	0.5
Osceola	2 720	1912	0.2
Ottumwa	22 010	1911	4.0
Storm Lake	2 430	1912	0.5
Waterloo	26 690	1907	2.5

TABLE 9. — *Continued.*

City.	1910 Population.	Date Installed.	Capacity (M.G.D.)
KANSAS.			
Augusta	1 300	1911	0.5
Baldwin	1 390	1909	0.1
Burlingame	1 550	1913	0.3
Burlington	2 180	1914	0 8
Caldwell (P)	2 250	1890	0.5
Chanute	9 270	1914	1.0
Cherryvale	4 940	1911	1.4
Coffeyville	18 500	1913	4.0
Council Grove (P)	2 670	1914	1.0
Douglas	1 000	1914	0.3
Emporia	9 060	1915	3.0
Fredonia	3 040	1915	1.0
Garnett	2 330	1907	0.5
Horton	3 600	1912	1.0
Humboldt	2 550	1916	0.3
Independence	10 480	1914	4.5
Jewell City	1 000	1913	0.2
Kansas City	131 980	1910	11.5
Lansing	1 000	——	0.2
Lyndon	800	1913	0.3
Marysville	2 260	1914	0.5
Mound City	1 000	1911	0.3
Olathe	3 270	1914	0.5
Osage City	2 430	——	0.5
Osawatomie	4 050	1915	1.0
Oswego	2 790	1916	1.0
Paola (P)	3 210	1887	0.2
Parsons	12 460	——	3.0
Pleasanton	1 370	1915	0.2
Russell	1 690	1911	0.5
Washington	1 550	1914	0.5
Winfield	6 700	1894–1908	3.0
KENTUCKY.			
Ashland	8 690	——	3.0
Bardstown	2 130	1915	0.5
Bowling Green (P)	9 170	1910	3.0
Campbellsville	1 210	1914	0.5
Catlettsburg	3 520	——	4.0
Danville	5 700	1905	2.5
Frankfort	10 460	1912	6.0

TABLE 9. — *Continued.*

KENTUCKY. — *Continued.*

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Georgetown	4 530	1910	0.7
Henderson	11 450	1916	3.5
Hopkinsville	9 420	1897	0.5
Lancaster	1 510	1912	0.5
Lexington	35 100	1895	4.0
Louisville	263 260	1905–1914	72.0
Mt. Sterling	3 830	1912	1.0
Paducah	22 760	1904	7.0
Paris	5 860	1905	1.0
Shelbyville	4 700	1915	1.0
Somerset	6 880	1912	1.0
Winchester	7 160	1904	2.3
LOUISIANA.			
Morgan City	5 480	1912	1.0
New Iberia	7 500	1915	0.5
New Orleans	361 220	1909	44.0
Shreveport	28 020	1899–1916	7.0
MAINE.			
Bangor	24 800	1912	8.0
Belfast	4 620	1914	1.1
Biddeford	17 080	1910	5.5
Kennebunk (P)	3 100	1915	2.0
Mechanic Falls	1 680	——	0.7
Oldtown (P)	6 320	1901	1.5
Rumford Falls	5 430	——	0.5
Veazie	1 000	——	1.0
MARYLAND.			
Avalon	1 500	1910–1914	2.5
Baltimore	558 480	1914	128.0
Catonsville (P)	4 500	1890	0.3
Cumberland	21 840	1913	8.0
Elkton	2 490	1912	1.0
Hagerstown	16 510	1912	4.0
Havre de Grace	4 210	1906	1.0
Laurel	2 420	1915	0.5
Sparrows Point	4 000	1895	0.3
Tacoma Park	500	1910	0.3

TABLE 9. — *Continued.*

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
MASSACHUSETTS.			
Athol	8 530	1888	1.5
Cohasset	2 590	1914	1.0
Pepperell	3 000	——	0.7
Reading	5 820	1910	1.5
MICHIGAN.			
Adrian	10 760	1914	3.0
Ann Arbor	14 820	——	3.0
Dearborn	1 500	1914	2.0
Escanaba	13 190	1908	6.0
Flint	38 550	1912	9.0
Grand Rapids	112 570	1911	25.0
Iron River (P)	2 450	1907	0.2
Ironwood	12 820	1910	1.2
Menominee	10 510	1916	3.0
Mt. Clemens (P)	7 710	1888	1.0
MINNESOTA.			
Brainerd (P)	8 530	1897	0.5
Breckenridge	1 840	1910	1.0
Carlton	800	1916	0.2
Chisholm	7 680	1906–1914	2.0
Crookston	7 560	1911	0.5
East Grand Forks	2 530	1909	1.0
Ely	4 050	1904	1.0
Gilbert	1 700	1915	0.5
Kinney (P)	1 000	1916	0.3
McKinley (P)	500	1902	0.1
Minneapolis	360 360	1911	60.0
MISSOURI.			
Bertany	1 930	1912	0.3
Boonville	4 250	1905	1.0
Butler	2 890	1916	0.5
Canton (P)	2 220	1911	0.2
Carthage	9 480	1905	2.0
Chillicothe	6 270	1915	1.2
Excelsior Springs	3 900	1914	1.0
Hermann	1 590	1912	0.7
Holden (P)	2 010	1893	0.3

TABLE 9. — *Continued.*

MISSOURI. — *Continued.*

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Independence	10 070	1905	1.0
Joplin	32 070	——	7.0
La Grange (P)	3 260	1914	0.3
Lamar	2 320	1891	0.3
Liberty	2 980	1912	0.5
Louisiana (P)	4 450	1888–1889	1.8
Macon	3 580	1914	0.7
Maryville (P)	4 760	1913	0.8
Mexico (P)	5 940	1889	0.8
Monroe City	1 950	1913	0.4
North Kansas City	1 000	1913	0.5
Palmyra	2 170	1914	0.4
Paris	1 470	1916	0.5
Rich Hill (P)	2 760	1886	0.3
Sedalia	17 820	1915	3.0
St. Joseph (P)	77 400	1898	14.0
St. Louis	734 670	1914	160.0
Shelbina	2 170	1911	0.4
Slater	3 240	1916	0.6
Springfield	35 200	1910	6.0
Trenton (P)	5 660	1916	1.2
Washington (P)	3 670	1888–1904	0.7
MISSISSIPPI.			
Columbus	8 990	1899–1907	2.0
Jackson	1 910	1915	5.0
Macon	2 020	1906	0.3
Meridian	23 290	——	3.0
Vicksburg	20 810	1904	3.0
MONTANA.			
Billings	10 030	1915	6.0
Chinook	1 000	1915	0.5
Great Falls	13 950	1916	12.0
Harlem	800	1911	0.3
Miles City	4 700	1910	2.0
Glendive	2 430	1916	2.0
NEBRASKA.			
Nebraska City (P)	5 490	1891	0.4

TABLE 9. — *Continued.*

NEW HAMPSHIRE.

City.	1910 Population.	Date Installed.	Capacity (M.G.D.)
Berlin	11 780	——	1.5
Exeter (P)	4 900	1887	0.2
Lebanon	5 720	1907	1.0

NEW JERSEY.

Allenhurst (P)	500	1910	0.5
Allentown	800	1910	0.1
Asbury Park (P)	10 150	1895	2.0
Atlantic Highlands (P)	1 650	1894–1910	1.0
Bordentown (P)	4 250	1890	0.5
Bound Brook (P)	3 970	1913	2.0
Bridgeton	14 210	1913	3.0
Burlington	8 340	1910	3.0
Elizabeth (P)	——	——	1.5
Flemington	2 690	1914	0.3
Franklin	2 400	1914	0.1
Gloucester	9 460	1904	2.0
Heightstown	1 880	1899	0.3
Keyport	3 550	1895	0.5
Keansburg Beach (P)	1 000	1912	0.2
Kirkwood	1 000	——	0.2
Lakewood (P)	5 150	1899	0.5
Little Falls	425 000	1902	43.0
Long Branch (P)	13 300	1888–1894	3.0
Merchantville (P)	2 000	1911	1.0
Moorestown	4 000	1905	1.0
Mt. Holly	5 750	1902	2.0
New Milford	425 000	1906	48.0
New Brunswick	23 390	1916	6.0
Penn Grove (P)	2 120	1910	0.5
Rahway (P)	9 340	1907–1910	10.6
Raritan (P)	8 730	1885–1913	3.0
Red Bank	7 400	1900	12.0
Roebling	1 500	——	1.0
South Plainfield	500	1906	0.4
Trenton	96 820	1914	30.0

NEW MEXICO.

Raton	4 540	1914	1.5

TABLE 9. — *Continued.*

NEW YORK.

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Albion	5 020	1914	1.0
Attica (P)	1 870	1896	0.4
Bainbridge (P)	1 160	1911	0.3
Batavia	11 610	1916	3.0
Binghamton	48 440	1902–1913	17.0
Brockport	3 580	1905–1913	2.5
Brooklyn	65 000	1903	8.0
Charlotte (P)	1 940	1907	0.5
Cobbleskill (P)	2 090	1914	0.6
Cohoes	24 710	1910	8.0
East Worcester (P)	1 000	1911	0.3
Elmira	37 180	1897	7.0
Fort Porter (P)	1 000	1914	0.3
Green Island	4 740	1902	1.0
Hilton	1 000	1915	0.3
Hornell (P)	13 620	1899–1904	3.0
Ithaca	14 800	1903	3.5
Kingston (P)	25 910	1892–1902	6.0
Kirkwood (P)	1 000	1912	0.3
Lewiston	1 000	1916	0.3
Le Roy	3 770	1915	0.5
Lyons	4 460	1915	1.0
Madrid	1 000	1915	0.3
Middletown (P)	15 310	1900–1909	5.0
Mt. Morris (P)	2 780	1914	0.5
Niagara Falls	30 450	1910–1912	26.0
North Tarrytown	5 420	——	3.0
Norwich (P)	7 420	1904–1907	3.0
Oneonta (P)	9 490	1906	3.0
Owego (P)	4 630	1887–1893	0.8
Pleasantville (P)	2 210	1908	0.1
Rensselaer	10 710	1901	4.0
Richfield Springs (P)	1 500	1889	0.4
Riverhead (P)	2 750	1914	1.0
Rochester (P)	32 000	——	4.8
Rouse's Point	1 640	——	0.1
Seneca Falls	6 590	1912	2.0
Sidney (P)	2 510	1904	0.3
Sonyea	1 500	1915	1.0
Stamford (P)	1 000	1899	0.2
Suffern (P)	2 660	1911	0.4

TABLE 9. — *Continued.*

NEW YORK. — *Continued.*

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Tarrytown	5 600	——	2.5
Valatie (P)	1 220	1894	0.2
Walton (P)	3 100	1914	1.5
Waterford	3 250	1914	2.0
Watertown	26 730	1902	10.0
Watervliet	15 070	1915	4.0
Watervliet Arsenal (P)	1 500	1900–1908	0.4
Williamson	1 500	1915	0.5
Youngstown (P)	1 000	1915	0.3
NORTH CAROLINA.			
Albemarle	2 120	1913	0.5
Asheville	20 160	1894	1.0
Bessemer City	1 530	——	0.6
Biltmore (P)	1 500	1897	0.5
Canton (P)	1 390	1915	0.5
Charlotte	34 010	1896–1905	5.5
Concord	8 710	1911	0.5
Durham	22 860	1916	3.0
Elizabeth	8 410	1906	0.5
Fayettesville	7 040	1911	1.0
Gastonia	5 760	1900–1908	0.7
Goldsboro	6 110	1913	0.5
Greensboro	18 390	1903	2.5
Greenville	4 100	1905–1913	0.6
Hamlet	2 170	——	0.5
Henderson	4 500	1912	1.0
Hendersonville	2 820	——	0.5
High Point	11 810	1893–1911	3.0
Louisburg	1 780	1905	0.3
Lumberton	2 230	1916	1.0
Mt. Airy	3 840	1913	0.3
Pinehurst	1 500	1911	0.5
Raleigh	19 220	1887–1913	4.0
Reidsville	4 830	1913	0.5
Rocky Mount (P)	8 050	1900–1909	1.4
Salisbury	7 150	1916	0.8
Sanford	2 280	1907	0.4
Shelby	3 130	1911	1.0
Smithfield	1 350	1912	0.3
Southern Pines	1 500	1910	0.5

TABLE 9. — *Continued.*

NORTH CAROLINA. — *Continued.*

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Statesville	4 600	1912	0.5
Tarboro	4 130	1911	0.5
Waynesville	2 010	1910	0.5
Weldon	2 000	1913	0.4
Wilmington	25 750	1906–1909	4.0
Wilson	6 720	1916	2.3
Winston-Salem	29 030	1904–1910	2.5
Washington	1 500	1914	1.0
NORTH DAKOTA.			
Fargo	14 330	1911	4.0
Grand Forks	12 480	1910	2.0
Minot	6 190	1910	1.0
Sykeston (P)	500	1915	0.1
Wahpeton	2 740	1914	1.0
Williston	3 120	1914	0.7
OHIO.			
Akron	69 070	1915	20.0
Alliance	15 080	1913	6.0
Ashtabula	18 270	1908	6.0
Attica	———	1915	0.2
Barnesville	4 230	1915	0.5
Batavia	1 030	1899	0.1
Bellaire	12 950	1905	5.0
Bucyrus (P)	8 120	1887–1904	1.5
Cambridge	11 330	1915	2.2
Cedar Point	1 000	1913	0.6
Cincinnati	416 120	1906	112.0
Columbus	204 570	1906	30.0
Conneaut	8 320	1904–1912	1.5
Dennison	4 010	——	2.0
East Liverpool	20 390	1915	6.0
East Youngstown	4 970	1916	1.0
Elyria	14 820	1907–1911	4.0
Geneva	2 500	1902	0.7
Huron	1 760	1909	0.5
Ironton	13 150	1916	4.0
Jefferson	1 460	1908	0.8
Lakeside	750	1912	0.2

TABLE 9. — *Continued.*

OHIO. — *Continued.*

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Lorain	28 890	1906	6.0
Marietta	12 920	1904	4.0
Massillon (P)	13 880	1888	0.7
Medina	2 730	1916	1.0
Napoleon	4 010	1915	1.5
Newark	25 400	1900	2.0
Niles	8 360	1911	3.0
Oberlin (P)	4 370	1903	1.0
Painesville	5 500	1915	2.5
Port Clinton	3 310	1911	1.5
Portsmouth	23 480	1913	8.0
Rocky River	1 170	1907	0.5
Sandusky	20 000	1908–1912	10.0
Steubenville	22 390	1915	6.0
Tiffin	11 890	1913	1.0
Toledo	184 130	1909–1914	34.0
Upper Sandusky	3 780	1904	1.0
Vermilion	1 370	1904	0.3
Warren	11 080	1916	5.5
Waverly	1 800	1910	0.5
Wellington	2 130	1915	0.5
Willoughby	2 070	1914	1.0
Woodsfield	2 500	1914	0.6
Youngstown	91 650	1905–1915	28.0
OKLAHOMA.			
Altus	4 820	1916	0.4
Anadarko (P)	3 440	1910	1.5
Ardmore (P)	8 620	1910	1.5
Bartlesville	6 180	1912	1.0
Blackwell	3 270	1909	1.0
Caddo	1 140	1915	0.3
Chickasha	10 320	1910	1.0
Claremore	2 870	1911	1.0
Clinton	2 780	1910	0.8
Durant (P)	5 330	1911	1.0
Guthrie	11 650	1910	1.5
Hominy	500	1914	0.1
Henryetta	2 230	1916	1.0
Holdenville	2 300	1912	0.5
Muskogee	25 280	1912	12.0

TABLE 9. — *Continued.*

OKLAHOMA. — *Continued.*

City.	1910 Population.	Date Installed.	Capacity (M.G.D.)
Oklahoma City	64 210	1906	8.0
Pauls Valley	2 690	1908	0.5
Pawhuska	5 030	1907	0.5
Pryor (P)	1 800	1912	0.7
Sapulpa	8 300	1911	2.0
Shawnee	12 470	1904	1.5
Stillwater	3 440	——	0.5
Tishomingo	1 410	1911	1.0
Wagoner	4 020	1914	1.0
Yale	500	1915	0.1
OREGON.			
Albany	4 280	1912	3.0
Arlington	500	1911	0.2
Eugene	9 010	1906–1911	4.0
Hood River (P)	2 330	1913	0.1
McMinnville	2 400	1911	0.5
Milton	1 280	1915	1.0
Oregon City	4 290	1910	1.5
Roseburg (P)	4 740	1907	1.0
Springfield	1 840	——	1.0
Wauna (P)	500	1913	0.1
PENNSYLVANIA.			
Arnot	2 500	1890	0.1
Beaver Creek	3 460	1910	0.6
Beaver Falls	12 190	——	8.0
Berwick	5 360	1913	2.0
Bethayres	400	——	1.5
Bethlehem (P)	12 840	1912	0.6
Bloomsburg	7 410	1912	3.0
Bristol	9 260	1906	2.0
Brookville	3 000	1910	1.0
Brownsville	2 320	1915	2.0
Butler	20 730	1905	5.0
California	2 230	1914	0.5
Cambridge Springs	1 510	1908	1.0
Canonsburg	3 890	1910	2.0
Canton	1 640	1899	0.5
Carlisle	10 300	1911	2.0

TABLE 9. — *Continued.*

PENNSYLVANIA. — *Continued.*

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Catasauqua	8 650	1914	2.0
Centerville	1 410	1916	0.3
Charleroi	9 620	1910	3.0
Chester	38 540	1916	12.0
Clarion	2 610	1900	0.5
Columbia	11 450	1904	2.0
Connellsville (P)	12 850	——	2.0
Danville	7 520	1914–1915	1.5
Eaglesmere	200	——	0.5
East Greenville	1 240	1912	0.3
Ellwood City	5 200	1909	3.0
Emlenton	1 110	1915	1.0
Ernest	500	1907	0.1
Erie	66 530	1912	24.0
Franklin	2 100	1908	2.0
Freeport	2 250	1908	0.5
Gettysburg	4 030	1912	1.0
Greenville	5 910	1913	1.0
Harrisburg	64 190	1905	15.0
Henderson	6 000	——	1.0
Holmsburg (P)	20 000	1906	3.0
Hummelstown	2 130	1908	2.0
Indiana	5 750	1906	1.2
Iselin	——	1905	0.1
Jersey Shore	5 380	1915	1.0
Kittanning	4 310	1908	2.0
Latrobe	8 780	1912	3.0
Lebanon	19 240	1910	3.0
McDonald	2 540	1914	0.7
McKeesport	42 690	1908	6.0
Marianna	1 360	1911	0.5
Masonton	1 000	1911	0.5
Mechanicsburg	4 470	1908	0.5
Media	3 560	——	1.0
Middletown	5 370	1910	1.0
Midland	1 240	1914	0.8
Monessen	11 780	1909	1.0
Monongahela	7 600	1904	2.0
Montgomery	1 480	1912	0.2
Natrona	4 800	1915	0.7
New Bethlehem	1 620	——	0.1

TABLE 9. — *Continued.*

PENNSYLVANIA. — *Continued.*

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
New Brighton	8 330	1889	0.5
Newcastle	36 280	1898–	7.0
New Kensington	7 710	1912	3.0
Newport	2 010	1910	0.3
Norristown	27 880	1915	5.4
North East (P)	2 670	1908	0.5
Oakmont	3 440	1914–1916	4.0
Overbrook	500	1895	0.3
Parker	1 240	1911	0.1
Phoenixville	10 740	1913	3.0
Pickering Creek	1 000	1896	0.8
Polk	2 070	1913	1.0
Pottstown	15 600	1908	4.0
Punxsutawney	9 060	1909	2.0
Quarryville	800	1911	0.3
Ridgeway	5 410	1915	1.0
Riverton	———	1909	1.5
Royersford	3 070	1895	0.7
Sayre	6 430	——	0.2
Scranton	129 870	1909	6.0
Sharon	15 270	1915	6.0
South Bethlehem	19 970	191[illegible]	6.0
South Pittsburgh	70 000	190[illegible]	14.0
Sunbury	13 770	1905	5.0
Tarentum	7 410	1907–1914	4.0
Vandergrift	1 200	1899–	1.0
Warren	11 080	——	3.0
Washington	18 780	1901	4.0
Waynesburg	3 550	1901	1.0
West Reading	2 060	1914	0.3
Wilkesbarre	67 100	1895	14.0
Wilkensburg	18 924	1916	2.5
York	44 750	1890	6.0
RHODE ISLAND.			
Bristol-Warren	15 150	1912	3.0
East Greenwich (P)	3 420	1908	1.0
East Providence	15 810	1906–1914	3.0
Jamestown (P)	1 180	1909	0.5
Newport	27 150	1910	6.0

TABLE 9. — *Continued.*

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
SOUTH CAROLINA.			
Abbeville	4 460	1911	0.5
Anderson	9 650	1910	0 5
Camden	3 570	1902	0.5
Charleston	57 830	1902–1909	6.0
Cheraw	2 870	1914	0.7
Chester	4 750	1909	0.6
Columbia	26 320	1902–1906	8.5
Darlington	3 790	——	0.5
Dillon	1 760	1909	0.5
Gaffney	4 770	1905	0.5
Lawrens	4 820	1905	0.5
Rockhill	7 220	1910	1.0
Spartanburg	17 520	——	2.0
Union	5 620	1900	1.0
Yorkville	2 330	1911	0.5
SOUTH DAKOTA.			
Huron	5 790	1914	1.5
TENNESSEE.			
Chattanooga (P)	44 600	1888–1893	9.0
Clarksville	8 550	1910	2.0
Columbia	5 750	1915	1.0
Dyersburg	4 150	1904–1907	1.0
Knoxville	36 350	1904–1914	8.0
Maryville	2 380	1916	2.0
Morristown	4 010	1915	1.0
Murfreesboro	4 180	1907	0.5
TEXAS.			
Ballinger (P)	3 540	1911	0.5
Beaumont	20 640	1904	3.0
Brady	2 670	1912	0.3
Brownsville	10 520	1911	1.0
Brownswood	6 970	1914	1.0
Corpus Christi (P)	8 220	1915	1.5
Dallas	114 740	1913	15.0
Denison	13 630	1914	2.0
Fort Worth	73 310	1911	5.0
Graham	1 570	1910	0.2

TABLE 9. — *Continued.*

TEXAS. — *Continued.*

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Lagrange (P)	1 850	1891	0.2
Laredo	14 850	1910	2.0
Longview	5 160	1915	1.0
Paris	11 270	1909	1.0
Rosebud (P)	1 470	——	0.3
Temple	10 990	1911	2.0
Waco	35 570	1912	5.0
Wichita (P)	1 000	1904	0.3
VERMONT.			
Burlington	20 470	1908	2.5
White River (P)	2 600	——	0.1
VIRGINIA.			
Danville	19 020	1905–1915	3.0
Emporia	2 020	1909	0.8
Farmville	2 970	1907	0.5
Fort Myer	1 000	1902–1912	1.5
Front Royal	1 130	——	1.0
Manchester	14 000	1906	2.0
Martinsville (P)	3 370	1912	0.5
Newport News (P)	20 200	1906	0.3
Norfolk	67 450	1899	8.0
Petersburg	24 130	1901–1910	2.5
Portsmouth	33 190	1907	6.0
South Boston	3 520	1916	1.0
Virginia Beach (P)	500	1910	1.0
Waynesboro	1 390	1909	0.5
WASHINGTON.			
Centralia (P)	7 310	1906	1.0
Waitsburg	1 240	1906	0.5
WEST VIRGINIA.			
Benwood	4 980	1900–1906	1.5
Charleston	23 000	1906	5.0
Clarksburg	9 200	1910	3.0
Elm Grove	1 900	1912	1.0
Fairmont	9 710	1898	1.0
Franklin	——	1911	1.0
Glen Ferris (P)	200	1910	0.1
Huntington	41 520	1898–	4.0

TABLE 9. — *Concluded.*

WEST VIRGINIA. — *Continued.*

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Kanawha	300	——	0.5
Morgantown	9 150	1899	2.0
Sistersville	2 680	1916	1.0
Weston	2 210	1913	1.0
Williamson	3 560	1911	1.0
WISCONSIN.			
Appleton	16 770	1912	4.0
Marinette	14 610	1899	3.0
Merrill	8 690	1897	1.5
Kenosha	21 370	1916	8.0
Oshkosh	33 060	1916	6.0
South Milwaukee	6 090	1910	1.5
Stevens Point (P)	8 690	1899	0.5
WYOMING.			
Basin	1 000	1911	0.5
Cheyenne	11 320	1915	5.0
Powell (P)	——	1915	0.1
Worland	750	1912	0.5
CANAL ZONE.			
Colon (P)	——	1907	1.5
Corozal (P)	——	1910	1.0
Miraflores	——	1915	15.0
Panama (P)	——	1907	2.0

TABLE 10.

FILTRATION PLANTS IN CANADA.

City.	Date Installed.	Kind.	Capacity. (M.G.D.)
ALBERTA.			
Edmonton	1911	Rapid Sand	6.0
Lethbridge	1917	Rapid Sand	4.0
MacLeod		Rapid Sand	——
Medicine Hat	1914	Rapid Sand	6.0
MANITOBA.			
Brandon		Rapid Sand	1.0
Neepaawa		Rapid Sand	0.35
Winnipeg Agr. College.	1913	Rapid Sand	1.0
NEW BRUNSWICK.			
Fredericton	1912	Rapid Sand	2.0

TABLE 10. — *Continued.*

ONTARIO.

City.	Date Installed.	Kind.	Capacity. (M.G.D.)
Arnprior	1901	Rapid Sand	0.5
Chatham	1895–1913	Rapid Sand	2.0
Coburg		Rapid Sand	1.4
Deseronto	1896	Rapid Sand	0.5
Danville		Rapid Sand	0.5
Haileybury		Rapid Sand	1.0
Hamilton		Slow Sand	12.0
Kitchener		Rapid Sand	0.4
Orilla	1914	Rapid Sand	2.07
Owen Sound		Slow Sand	2.0
Perth		Slow Sand	0.5
Renfrew	1897–1907	Rapid Sand	0.7
St. Thomas	1891–1902	Rapid Sand	2.0
Sturgeon Falls		Rapid Sand	——
Thyrso		Rapid Sand	0.1
Toronto		Slow Sand	40.0
Toronto		Rapid Sand	50.0
Wallaceburg	1914	Rapid Sand	0.65
Weston	1910	Rapid Sand	0.29
Whitby		Slow Sand	0.3
Welland	1914	Rapid Sand	0.25

QUEBEC.

Ahuntsic	1910	Rapid Sand	0.5
Aylmer	1917	Rapid Sand	1.0
Buckingham		Rapid Sand	1.5
Cartierville	1915	Rapid Sand	1.0
Cowansville	1912	Rapid Sand	0.25
Fraserville		Rapid Sand	0.25
Laval des Rapides	1915	Rapid Sand	0.25
Longue Pointe	1911	Rapid Sand	0.75
Longueuil	1895–1913	Rapid Sand	1.7
Montreal*	1913	Rapid Sand	30.0
Point Autrembles	1911	Rapid Sand	0.25
Ste. Hyacinthe	1917	Rapid Sand	4.0
Sault-au-Recollet	——	Slow Sand	1.0
Shawinigan Falls	——	Rapid Sand	1.0
Ste. Rose	1915	Rapid Sand	1.0
Three Rivers	1909–1911	Rapid Sand	3.45
Verdun	1908	Rapid Sand	1.0
Windsor Mills		Rapid Sand	——

* Supplies Maisonneuve, Outremont, and Westmount.

TABLE 10. — *Concluded.*

SASKATCHEWAN.

City.	Date Installed.	Kind.	Capacity. (M.G.D.)
Prince Albert	1910	Rapid Sand	0.9
Saskatoon	——	Rapid Sand	4.0

TABLE 11.

LIST OF FOREIGN RAPID SAND FILTER PLANTS.

City.	Capacity in Million Gallons Daily.
EAST AFRICA.	
Lourenco Marques	0.775
SOUTH AFRICA.	
Kroonstad	0.66
AUSTRALIA.	
Broken Hill, New South Wales	1.50
AUSTRIA.	
Trieste	5.35
CEYLON.	
Colombo	10.17
Ragama Cooly Camp	0.231
EGYPT.	
Alexandria	16.00
Benha	1.00
Benhi Souef	1.00
Cairo	20.00
Damanhour	1.00
Damietta	1.00
Mansurah	1.58
Zagazig	1.7
ENGLAND.	
Hamilton	2.00
Wolverhampton	1.20
York	5.40
FRANCE.	
Annecy	0.74

TABLE 11. — *Continued.*

City.	Capacity in Million Gallons Daily.
GERMANY.	
Posen	7.90
HOLLAND.	
Alblasserdam	0.384
Oldenzaal	0.384
Ridderkirk	0.384
Ysselmonde	0.300
HUNGARY.	
Rimamurany	0.147
INDIA.	
Bangalore	3.6
Chandernagore	0.665
Dacca	2.6
Davengeri	0.42
Dehli	1.86
Ernakulam	0.65
Erode	0.63
Hazaribagh Jail	0.28
Hubli	1.6
Jagdalpur	0.276
Jorhat	0.18
Kanchrapara	0.33
Kolar Gold Fields	2.4
Manipur	0.228
Masulipatam	1.19
Mysore	2.48
Naini Tal	0.333
Naraingange	0.66
Pudukkottai	0.228
Ramnaggar	0.398
Secunderabad	1.86
Silchar	0.353
Simla	0.58
Sylhet	0.745
Tezpur	0.276
ITALY.	
Genoa	19.6
JAPAN.	
Kyoto	20.2

TABLE 11. — *Concluded.*

City.	Capacity in Million Gallons Daily.
KOREA.	
Riuzan	1.0
CHINA (MANCHURIA).	
Inkao	1.33
NORWAY.	
Christiania	0.2
PERU.	
Piura	0.06
ROUMANIA.	
Galatz	1.22
RUSSIA.	
Armavir (Caucasus)	0.37
Arsamass	0.145
Balashov	0.33
Baku-Kura	0.33
Borgom (Caucasus)	0.145
Christopol	0.33
Helsingfors (Finland)	7.26
Nizhni-Novgorod City	2.31
Nizhni-Novgorod Fair	1.32
Novotcherkask	0.44
Petropavlovsk (Siberia)	0.33
Ribinsk	0.66
Rostov-Don	3.96
Sarapul	0.33
Semipalatinsk (Siberia)	0.33
Simbirsk	0.66
Tobolsk (Siberia)	0.55
Tomsk (Siberia)	2.44
Tsaritsyn	0.97
Vladimir-on-Kliazma	0.33
SIAM.	
Bangkok	8.00
STRAITS SETTLEMENTS.	
Johore	0.553
Lower Perak	1.44
Singapore Harbor Supply	0.178
Sungei Siakup	0.245

Early Conceptions of Water Filtration.

The earliest type of water filter was a bed of porous material through which water was passed to free it of visible impurities. So far as its relationship to disease prevention is concerned, filtration of municipal water supplies is an art which has been developed within the past thirty years. Some of the ancients had vague ideas of its hygienic usefulness, but for the most part such conceptions grew out of an apparent desire to obtain clearer or cleaner water. Although the germ theory of disease was not advanced until 1849, and although the idea that disease in any form could be water borne had its practical genesis at about that time, it seems certain that some of the early philosophers came to the conclusion that something more than mere clarification was effected by water filtration. Thus we find in *"Ousruta Sanghita,"* a book of medical lore written in Sanscrit probably some four thousand years ago, the statement: " It is good to keep water in copper vessels, to expose it to sunlight, and filter through charcoal." The writings of Hippocrates and Pliny also disclose facts which indicate clearly that the ancients had some regard for pure water and a distrust in polluted waters.

Similarly, William Walcott's patented process (1675) for " making water corrupted fit for use " undoubtedly aimed at something more than mere clarification, but it is equally certain that the inventor did not know just what; and in 1790 Johanna Hempel patented a contrivance for filtering water, using sand, gravel, and pulverized glass as the filtering media. It was not until 1829, however, that the first municipal water filter of which there is comprehensive record was built by the Chelsea Water Company at East Chelsea, London, in compliance with the recommendations of the Royal Commission on the Metropolitan Water Supply. This filter was designed to operate merely as a mechanical strainer to effect clarification, although it is significant that in the same year that this filter was built, typhoid fever was recognized as a specific disease. The germ of that disease was not discovered until 1880, some fifty years later, and it was not well understood until 1884, or some thirty-three years ago.

About twenty years after the construction of the East Chelsea filter, the British Empire was visited by a severe cholera epidemic,

and at about the same time the theory was advanced by an English scientist that cholera was a water-borne disease and that the general cause of the epidemic could be traced to the polluted water supply. Three years later (1852) came the first really important step in water filtration history. This took the form of an act of Parliament which made compulsory the filtration of the entire water supply of the Metropolitan District of London.

In 1883 Koch discovered the cholera spirillum in Calcutta water, and in 1889 Brouardel attributed 90 per cent. of all cases of typhoid fever to water.

As late as 1892, or twenty-five years ago, the hygienic efficiency of water filters of the slow sand type was seriously questioned by a large number of medical authorities and engineers. Their arguments against filtration were based very largely upon such occurrences as the outbreak of typhoid fever in that portion of Berlin, Germany, which was supplied with filtered water from the old Stralau works. Many sanitarians did not hesitate to express the conviction that filtration of impure water was an ineffective safeguard against water-borne diseases, and altogether improper, and that public water supplies should be drawn only from pure mountain streams and ground waters. The abandonment of filtered Thames water in favor of water from mountain streams was strongly advocated for London, and the current literature of that day showed a preponderating tendency against filters in general. At this date, however, the great majority of sanitarians in the civilized world are advocating filtration. In Germany, the filtration of surface water supplies has been almost uniformly compulsory for over twenty years, and impounded unfiltered supplies are found in but few important cities.

While practical modern water filtration, if we may use the term, sprang into existence with the construction of the small East Chelsea filter in 1829, and while the art developed slowly in England and on the Continent during the ensuing sixty years, it remained for the stupendous cholera epidemic in Hamburg in 1892, and the happy experience of Altona, the sister city of Hamburg, to stamp indelibly on the public mind the conviction that impure water is responsible for much of the public sickness, and to furnish unmistakable proof of the efficacy of water filtration in making

polluted water safe and minimizing the dangers invariably arising from the consumption of such waters. Actually, then, water filtration as an accepted science, and the important developments therein must be considered as about twenty-five years old or less.

It is also well known that as late as 1885, judged by comparative chemical analysis of raw and filtered water, the result was not at all favorably considered by sanitarians, as the purification effected by filtration, according to the standards of that time, was practically negligible. It is to be noted that in that day organic matter, whether living or dead, was believed to be the chief cause of water-borne disease. One of the most important factors in advancing the knowledge of water filtration at that critical period was the exhaustive work of Prof. Percy F. Frankland, who, in 1885, by applying the then modern methods of bacteriological analysis to water filtration, showed that while, from a standpoint of removal of the chemical constituents from water, filtration was a disappointment, it was a marked success in the removal from water of bacterial life.

It naturally took years, indeed generations, to bring matters to this sort of a head. Furthermore, there are to-day some sanitarians who consider water containing large amounts of organic matter as seriously affecting the purity and wholesomeness of the water regardless of how pure it may be bacterially, but the great majority now agree that, with a few unusual exceptions, it is the bacteria of disease-producing proclivities in water that determine its unwholesomeness. Finally, it is only during the past twenty-five years that water filtration has had a sound accredited standing. Frankland proved its bacterial efficiency thirty-two years ago, in 1885, as did the Massachusetts State Board of Health, and Continental investigators during the decade immediately following. It is also true, whether or not filtration was generally accepted as a safeguard against the dangers of impure water, that twenty-five years ago filtered water supplies were furnished to a total world population of 20 000 000, of which fully 99 per cent. were located in Europe and other foreign countries and about 1 per cent. in America. In 1917, however, 20 000 000 people are supplied with filtered water in North America alone, although fifteen years ago less than 2 000 000 were so supplied.

Theory and Practice in Water Filtration.

There are but two methods of filtration with records of practical accomplishment in the purification of municipal water supplies. These are commonly known as the "Slow Sand Method" and the "Rapid Sand Method." The former first appeared in the field, and the latter made its first official appearance in 1885. There were failures and indifferent successes, of course, but the early history of all accomplishments is freely dotted with such mishaps.

The success attending the use of slow sand filters in foreign countries is largely attributable to the fact that the waters upon which they operate are almost uniformly clear, that is, relatively free from suspended matters. Long years of study have proved that a slow sand filter, *per se*, cannot efficiently and economically purify a muddy water But this was not understood in the early days of filtration history, and when, in 1866, Mr. James C. Kirkwood was sent to Europe by the city of St. Louis to investigate water filtration practice, he returned with the recommendation that a slow sand filter be built for the purification of the Mississippi River supply for that city. His recommendations for St. Louis were not adopted, however, and fortunately, too, for none of the purification plants in Europe which came under Mr. Kirkwood's observation had a water to treat which in its physical characteristics was in any way similar to the Mississippi River. A few years before Mr. Kirkwood's death, however, the first slow sand filter in America was built at Poughkeepsie from plans prepared by him. The Hudson River water is not in the same class, physically, as the river waters of Western Europe, however, and material changes have since been made in the original plant and in its mode of operation. Plants of a type similar to the one at Poughkeepsie were built somewhat later at Lowell, Mass.; Columbus, Ohio; and Toledo, Ohio, but all failed of the purpose for which they were intended.

Scientific Investigation of Water Filtration.

The earliest investigations on slow sand filtration were conducted at Boston, Mass., and Louisville, Ky. Then followed the inauguration, in 1887, of the classic investigations of the Massa-

chusetts State Board of Health at Lawrence, Mass. These latter investigations were followed by the construction, in 1892–1893, of the Lawrence city filter for the purification of the badly polluted Merrimack River water, and the decision to build this filter doubtless was hastened by the Hamburg epidemic of 1892 and the appearance of cholera in New York Harbor in the same year.

Between 1887 and 1903 the water filtration experiments at Lawrence were confined to slow sand filters, but in the latter year a small gravity filter with a superficial filtering area of about four sq. ft., and containing 21 in. of relatively coarse sand (effective size 0.71 mm.), was put into operation as a rapid sand filter. The filters of the rapid sand type tested at the Lawrence Experiment Station since 1903 were as small as the first one (No. 216) or smaller.

Since 1903, the experiments at Lawrence have also covered slow sand filter operation, modified by the use of coagulating chemicals and with the allowance of a supplementary period of coagulation and sedimentation prior to filtration.

The first comprehensive tests of the rapid sand process of water filtration were conducted at Providence, R. I., in 1893–1894. Much more exhaustive experiments were started in the winter of 1895 at Louisvillle, Ky., continuing through the better part of two years thereafter. Similar investigations were carried on at Pittsburgh, Pa. (1897–1898); Cincinnati, Ohio (1898–1899); Washington, D. C. (1899–1900); New Orleans, La. (1900–1901); Harrisburg, Pa. (1903–1904); and elsewhere. Aside from the aid they rendered in the solution of the local problems, these carefully conducted investigations, which cost hundreds of thousands of dollars, more than anything else served to establish on a sound footing the entire reliability of the rapid sand process of water purification. These experiments were all conducted at a critical period in the history of this process, and the basic principles of the method were fully tested and proved.

The reports published upon the results of these various investigations were followed by a decade of extreme activity in filter construction. Between the dates 1900 and 1910, the decade in question, the number of people supplied with filtered water in the United States increased from 1 860 000 to 10 805 000, or nearly

sixfold. Of this increase, rapid sand filters provided 61 per cent. and slow sand filters 39 per cent. This was the most notable period of slow sand filter construction in the history of slow sand filtration in America. Since 1910 there have been but few important additions to the list of filters of this type built in this country. Rapid sand filter construction has steadily grown, however. Whereas between 1900 and 1910 new installations were made at the annual average rate of 78 million gallons daily filtering capacity, since 1910 the average annual rate of construction has been 139 million gallons of daily filtering capacity. The average rate of new slow sand filter installation since 1910 has been 13 million gallons daily capacity annually. The contrast is sharp.

Principal Differences between Rapid Sand Filtration and Slow Sand Filtration.

The essential differences between the rapid sand and slow sand processes of water purification lie in the character of the preparatory treatment given the raw water prior to filtration, the size of the filter units, the size of sand grains making up the filter bed proper, the rate at which water is passed through the filter, the kind of "head" used to force the water through the bed, and the manner in which the beds are cleaned.

Both types of filters are composed of sand, and consequently, so far as strict nomenclature is concerned, they are both sand filters. The normal slow sand filter is operated at a rate about one fortieth of that employed in a normal rapid sand filter, thus properly giving to each their distinguishing names of slow and rapid sand filters.

The slow sand filter is cleaned by scraping off the top layer of clogged material, washing and replacing the sand removed with this material. The rapid sand filter is cleaned by introducing filtered water through the strainer system at the bottom of the bed and allowing the dirt which has accumulated in the filter to flow off to the sewer through gutters located near the surface of the sand bed.

In the original slow sand filters the water was applied directly to the sand bed without any preparatory treatment except that

which it may have undergone in storage and impounding reservoirs, or in settling basins. In this country such plants are found at Lawrence, Mass.; Providence, R. I.; New Haven, Conn.; and Reading, Pa. In the attempt to apply the slow sand process to the purification of muddy water it was early found necessary to make use of long periods of sedimentation prior to filtration, or to use coagulating chemicals whereby the suspended matters would be gathered together in aggregates and settled out in the coagulating and sedimentation reservoirs before the thus partially clarified water was applied to the final slow sand filters. In the rapid sand process the use of a coagulating chemical is standard procedure, and always has been. It was that feature of the process which made it patentable, and it was on this idea that the original patent covering the rapid sand filter process was granted to Mr. John W. Hyatt in 1883.

Preparatory Treatment of Water for Filtration.

Those who have studied water purification practice in connection with many types of waters have been forced to the conclusion that where the water is markedly colored, or possesses a turbidity in excess of thirty parts per million (0.0039 oz. per gallon), or where there are sharp fluctuations in the character of water ordinarily but slightly colored or turbid, rapid sand filters are best adapted to its purification. This does not mean that just as good or better results may not be obtained with a rapid sand filter as with a slow sand filter in the treatment of waters which fall within these low limits of imperfection. The practice of years has virtually fixed these limits for slow sand filters. In these days where final sterilization of filter effluents is so largely practiced, and should be the uniform custom, the decision as to whether slow or rapid sand filters should be adopted for the solution of a given water problem should rest upon the proposition as to which process will yield a filtered water of satisfactory physical characteristics at the lowest total cost.

The majority of our American rivers are in the muddy water category; that is, while perhaps for a considerable part of the time the water may be relatively free from turbidity, much of the time it is heavily charged with suspended matters washed into it by rains

or melting snows. This is one excellent reason why slow sand filters have not been so widely used as rapid sand filters, and why the largest slow sand filter installations in this country have failed as such, and have undergone radical modification in their physical makeup and in the mode of their operation.

Many American streams and lakes are relatively clear but heavily colored by vegetable stains. Decoloration by exposing the water to the sun's rays is not particularly effective, and is patently unreliable, since the sun cannot be expected to shine every day, nor but a part of any day. Then, again, sun bleaching is actively felt for a depth of not more than about one foot beneath the surface, and a month's exposure of such a shallow layer of water to the sun's rays will effect decoloration only to the extent of about 20 per cent.

Filtration of colored water through clean quartz sand will not effect measurable decoloration, and it is well known that, without the aid of a coagulating chemical, slow sand filters will not consistently remove from water more than about 20 per cent. of the dissolved color. The most practical, effective, and satisfactory method of water decoloration of which we now have knowledge is coagulation followed by rapid sand filtration. The author believes he has ample grounds for this statement, not the least being the conclusion of Mr. Allen Hazen, in his book, "Clean Water and How to Get It" (1914, pp. 95–96):

"Sand filters are used in connection with various preliminary treatments, but, generallly speaking, they are adapted to treating only such waters as are capable of being purified in that way without any preliminary treatments, or with only rough and inexpensive treatments. If water ordinarily requires coagulation, then, as a rule, it will be better to make the coagulation thorough and use mechanical (rapid sand) filters for the final treatment."

Except at the expense of much space, and by perhaps encroaching unduly on the subject of slow sand filtration, which is to be discussed by Mr. Goodnough, the author cannot well detail the departures from this important conception in filter practice which have been made at Albany, N. Y.; Philadelphia and Pittsburgh, Pa., and elsewhere. The slow sand filters alone failing efficiently and economically to purify the waters of the Hudson, Schuylkill,

Delaware, and Allegheny rivers, highly expensive preparatory treatments like pre-filtration, or coagulation followed by pre-filtration systems, were later added to the plants as originally planned in order to get satisfactory effluents from the final slow sand filters. Mr. Goodnough doubtless will discuss thoroughly this phase of modified slow sand filter practice.

In rapid sand filtration a coagulating chemical, usually aluminum or iron sulphate, is used. The coagulant, on being added to water, is rapidly and completely decomposed by the alkaline compounds naturally present in the water. Ordinarily this alkalinity is due to dissolved carbonates and bicarbonates of lime and magnesia. Where aluminum sulphate is used, the sulphuric acid portion of the coagulating chemical displaces the weak carbonic acid of the alkaline compounds, and as a result, soluble sulphates of lime and magnesia are formed, and equivalent amounts of carbonic acid and alumina are liberated. The latter unites with the water and forms the white, insoluble, and gelatinous precipitate known as aluminum hydrate, which has the property of massing together the various suspended impurities and drawing out of solution the dissolved color which the water may contain. These aggregates of coagulated matter, possessing a relatively great hydraulic subsiding value, settle out quickly in basins provided for the purpose. The partially clarified water then flows to the rapid sand filters.

The prior removal of suspended and dissolved impurities in this way relieves the rapid sand filter of much of its burden, and it is thus enabled to continue in operation for a correspondingly longer period of time without becoming clogged. Delayed coagulation following the addition of the chemical to the water, and subsequent after-coagulation in the filters themselves, is also guarded against. It is important that the period of coagulation and sedimentation prior to filtration be long enough to insure thorough coagulation and the removal of the bulk of the coagulated matters, but it should not be so long as to allow the removal of too much of the coagulated floc, the presence in the water applied to the filter of a minor part of which is essential to the efficient performance of the filter. This is particularly true in the case of rapid sand filters of the gravity type, although there

are some rapid sand pressure filters operating efficiently on relatively clear waters where no coagulating and settling basins are provided ahead of the filters.

Coagulants are also used in some of the modified slow sand filter processes. In India, Japan, and elsewhere abroad, aluminum and iron salts are employed in the pre-treatment of water for filtration through slow sand filters. In America, coagulation forms an integral part of such modified slow sand systems as those at Albany and Poughkeepsie, N. Y.; Springfield, Mass.; Philadelphia, Pa.; Washington, D. C.; and Indianapolis, Ind. Where coagulants are thus used, and the water is better prepared for filtration, it has been found that slow sand filters can be operated at much higher rates of filtration than those normally employed. Such increases in the rate of operation of slow sand filters, made possible by the use of coagulants in the pre-treatment of the water, are in the nature of a step toward unification of the two leading filtration methods now existing, the basic principles involved in both processes being the same under these circumstances.

High rates of filtration in slow sand filters invite trouble through deep penetration of suspended matter into the filter bed, however, and this is almost inadmissible in such filters, tending as it does to produce unequal rates of filtration in different parts of the bed, and creating a factor of abnormal cost and difficulty when the beds are cleaned. Conversely, such penetration of coagulated matter into the rapid sand filter bed is not a detriment. This whole question of penetration will be further discussed beyond.

Size and Equipment of Filter Units.

Up to 1900 it was the practically uniform custom to build rapid sand filter tanks of wood or steel, the filters having unit filtering capacities of about two thirds of a million gallons per day. With the construction of the 32 000 000-gal. rapid sand filter plant at Little Falls, N. J., in 1902, tanks of rectangular concrete construction came into use, and have grown in popularity since that time. The Little Falls filter plant is composed of thirty-two rectangular concrete filter units, each having a capacity of one million gallons. The largest rapid sand filter units are those at Cincinnati, which are roughly four times the size of the Little Falls units.

The early filter tanks of wood or steel were circular in plan. Some of them were divided into two compartments, the upper compartment containing the filter bed and the lower compartment serving as a coagulating basin. The strainer manifold system was situated on the upper side of the floor separating the coagulating compartment from the filter bed, on which the latter rested. In other types of gravity filter tanks the coagulating compartment was omitted, and coagulation and sedimentation carried on in detached basins. These are known as low type filters; the others, as high type filters.

For washing the filters, provision was made for forcing filtered water in a reverse direction through the strainer system on which the filter bed rested. During washing operations in some filters, agitators in the shape of iron teeth extending vertically from a revolving horizontal arm served to thoroughly mix the sand while the wash water was flowing through it, thus loosening up the bed, breaking up clogged masses, and freeing the sand of the accumulation of foreign matters removed from the water. In other types of filters the agitators were eliminated, compressed air being applied to the bed in the same manner as the wash water. Features in connection with filter washing will be discussed beyond, under a specific heading.

It may not be out of place to point out here that slow sand filters are usually constructed in units of about one acre or less in area, and that from such filters a daily yield of 3 000 000 gal. per acre is obtained, whereas from the same area of rapid sand filters 125 000 000 gal. of filtered water is secured.

The Operation of Filters, with Particular Reference to the Rate of Filtration, the Use of Negative Head, and the Penetration of Suspended Matter into the Filter Bed.

The sand comprising the filter bed proper in slow sand filters is relatively somewhat finer and less uniform in size of particles than that employed in the rapid sand filter. As filtration of impure water through a slow sand filter proceeds, there accumulates on the immediate surface of the filter a gelatinous film of organic and mineral matter. This film when formed serves to increase

materially the efficiency of the filter. With its integrity to be maintained continuously, it is obviously necessary that the rate of passage of water through it be kept practically uniform, and that it be not so high as to allow the passage of the accumulated matters materially below the surface of the sand layer. If deep penetration occurs in a slow sand filter, great difficulty is experienced in scraping off the dirty stratum, and the process is not only difficult, but costly as well. This is readily understood when it is stated that for every inch scraped from the surface of one acre of slow sand filter, 134 cubic yards of material are removed.

In slow sand filters, only positive head is utilized to force the water through the filter. By positive head is meant that head afforded by the depth of the column of water standing over the surface of the filter bed. Negative heads cannot be used in the operation of slow sand filters. By negative head is meant any head in excess over that corresponding to the depth of the column of water standing over the filter surface.

As filtration through a slow sand filter proceeds after the positive head has been exhausted and negative head is being utilized, the latter, which is analogous to suction, reduces the pressure on the water within the sand layer to a point where the water will give off air and this air will collect in the interstices of the sand layer. These accumulations of air increase the frictional resistance in the filters so rapidly that only a comparatively small quantity of water can be filtered after the loss of head equals the positive head or depth of water above the sand.

With rapid sand filters, these basic principles in the operation of a slow sand filter are directly reversed. The sand composing the filter bed proper is made up of coarser grains, and the size of these sand grains is more uniform. It follows that the frictional resistance to the passage of water through such a bed is lower than in the case of slow sand filters composed of relatively finer sand of lower uniformity in size of particles. Whereas in the latter type of filters the active filtering stratum is immmediately at the surface of the sand layer, and where deep and irregular penetration into the sand layer of suspended matters is inadmissible, in rapid sand filters the zone of filtering activity is not only at the immediate surface, but extends for a foot or more into the bed, due to pene-

tration of the foreign suspended matters in the water deep into the surface layers of the filter itself.

The rapid sand filter may be operated efficiently on either positive or negative head; in fact, the outlet piping of most rapid sand filters is so arranged as to allow of the utilization of the latter; whereas, in the slow sand filter the use of negative head results in the separation of air from the water through the formation of a partial vacuum directly beneath the clogged surface layer, and this increases the frictional resistance to the passage of water through the filter and thus sharply diminishes its filtering activity. In a rapid sand filter, however, when the loss of head enters the field of negative head, and a partial vacuum is formed beneath the clogged surface layer, the rapid passage of the water through the filter, amounting to practically forty times the velocity of the passage of water through a slow sand filter, and the exit of this water through the outlet pipe produces in effect a suction action on the sand layer itself.

Since in slow sand filters the rate at which water is passed through the sand layer is very low, the filtering material in such a bed naturally is not so closely compacted as is the case where the rate of passage of water through the sand layer is much higher than this, as is the case in rapid sand filter operation. Compacting in a filter bed is an important factor. If it is very great, the bed offers increased resistance to abnormalities in the rate of passage of water through it; the bed is hard, and the sand grains are closely packed together. In a rapid sand filter such is the condition.

The compacting of sand in a filter bed is partly due to pressure. The lower layers of a tank full of sand sustain greater pressure than the upper layers, owing to the weight of the sand above and to the weight of the water in and above the sand. It is, therefore, easily seen that the pressure increases downward, and there must also be an increasing compactness of the sand grains downward due to this pressure. Compacting of sand is also due to the velocity of the flow of water through it. The greater the velocity of flow of water through a sand layer, the greater is the tendency to rearrange the particles by washing the smaller particles downward and thus fill up the interstices lower down. The velocities of flow of water

through a slow sand filter are low, and there is comparatively little disturbance of the sand grains, but in a rapid sand filter the velocities are some forty times higher and the disturbance is bound to be much more marked.

Positive head alone, due to atmospheric pressure, plus the weight of water in and above the sand layer, adds a certain amount of pressure, but the pressure on the plane of maximum resistance is the total head, and this pressure keeps increasing as the loss of head increases. It makes no difference when the total loss of head passes the positive head point and enters the field of negative head. With airtight clogging of any stratum in the sand bed, there will be no compacting of the sand layer except that due to velocity. But increased pressure or suction produces an increased velocity of flow of water through the voids, and this increased velocity probably has some tendency to rearrange the sand grains.

To take a concrete example of compacting in a sand filter, if we loosely pour sand into a receptacle containing water, the sand obviously will settle to the bottom, one grain resting against another. It does not matter how deep the water is into which the sand is poured. If the receptacle is not shaken, more water could be added and no increase in compactness would result. The reason for this is that each individual grain of sand would be under more pressure the greater the depth of the water, but as this pressure is equal in all directions, it has no effect on compacting. Now make an opening in the bottom of the receptacle below the sand and let the water flow downward by gravity through the voids of the sand. The friction of the flowing water against the sand grains pulls them together more closely, compacts them physically, and at the same time rearranges the particles so that the fine fill into the voids of the coarse. This makes the total voids less, and as a consequence the velocity of flow through the bed becomes greater. This produces more compression and more rearranging.

An interesting summation of the action of slow sand and rapid sand filters when operating under positive and negative heads is contained in the report of Mr. George W. Fuller on the tests conducted at Cincinnati in 1898–1899. On pages 364–366 of this

report Mr. Fuller states that successful use was made of negative head in connection with the operation of the rapid sand filter, but that slow sand filters failed when operated under negative head. Mr. Fuller says in this connection:

"In slow sand filters, the section of maximum frictional resistance is always at and just below the surface of the sand layer. Accordingly, when the acting head exceeds the depth of water above the sand, there is a united clogging action at this portion of the filter, due both to suspended matters removed from the water and the air evolved from it. As a result of the combined action, the yield of water after this time is very small.

"But in rapid sand filters of this construction the section of maximum frictional resistance is at the strainers, located at the bottom of the sand layer, until the filter has ordinarily been in operation for a large percentage of the length of the run between washings. Furthermore, the clogging at the surface is relatively much slower than in the case with slow sand filters, because the higher velocity in the rapid sand filters carries considerable portions of the suspended matters further down into the sand layer. Consequently we find primarily that in rapid sand filters negative heads with the evolution of air do not occur until the acting head has reached the depth of water above the sand plus the thickness of the sand layer. For some distance beyond this the acting head can be carried before the section of the filter near the surface of the sand layer becomes the one maximum frictional resistance. Until this time arrives, negative heads evolve air in rapid sand filters at the bottom of the sand layer (which is kept from rising apparently by the velocity of flow), and thus defer the time when suspended matters from the water and from the evolved air combine at the same portion (upper) of the sand layer to cause very rapid clogging."

With further reference to the results of the Cincinnati tests, it appears that by taking the results of representative runs on the rapid sand filter during the months of September, October, and November, 1898, with the total available positive head (Fuller's definition) of 4.5 ft. above the strainer system acting, less than one third of the total yield of the filter between washings was obtained, over 70 per cent. of the total yield of filtered water being obtained while the 5.5 ft. of negative or suction head below the strainer system was being utilized.

These data are of particular significance. When a certain

point is reached in the frictional resistance offered to the flow of water through the sand layer, the accumulation at the surface of the sand layer breaks under the suction action, allowing much of the accumulated matter to pass farther down into the bed. This occurrence may be repeated several times, causing the whole bed to act as a filtering medium instead of the surface only, as is the case in slow sand filters. When the original clogged layer at the actual surface of the sand layer is first broken, a new clogged layer begins to form underneath it, and this explains the striking yields of the filter when operating under negative head as referred to above.

The employment of a down draft pipe in connection with the slow sand filters, whereby use might be made of negative head, was not a success because of the fact that the slow sand filter became clogged with air. In regard to this point Mr. Fuller had the following to say in the Cincinnati report, page 146:

"The reason of this was that the negative head (suction) reduced somewhat the pressure upon the water, which during much of the time is saturated (practically speaking) with air, thus causing the air to separate out gradually from the water as it becomes supersaturated at the reduced pressure. This separation of air took place for the most part at and just below the section of maximum frictional resistance, which of course is at the surface of the sand layer. In consequence of the gradual separation and accumulation of air at this portion of the sand layer, it was found that the filter became clogged at a very rapid rate, comparatively speaking; and of the total quantity of filtered water with 13 ft. of head, only about 20 per cent. of the volume was obtained with the 9 ft. of negative head. As the filters grow older it is probable that this percentage would be smaller."

In connection with the failure to utilize negative head to advantage in the operation of slow sand filters, it seems clear that the reason for it is that the air drawn out of the water during its passage through the sand layer remains beneath the plane of maximum resistance or elsewhere within the bed; and that under the low velocity of flow of the water through the filter it is not carried downward and out of the outlet pipe, but remains in effect to air bind the bed. In the operation of a rapid sand filter it is always feasible to utilize negative head, for the reason that while air is separated out of the water during its passage through the filter it

does not become air bound. This is so because, under the high velocities of flow of water through a rapid sand filter, a large proportion of the air is drawn away from the plane of maximum resistance, wherever it may be at any particular time, and is carried down and out of the outlet pipe. It is this suction action and high velocity of flow of water through rapid sand filters which gives to the effluent a milky appearance in many cases due to the air bubbles that are carried out of the outlet pipe with the filtered water.

When the negative head is used in connection with a slow sand filter, and this filter becomes clogged and is put out of service for cleaning, when the clogged surface layer is scraped off it is found that the use of negative head has caused a release of air from the water and that the air upon breaking through badly disturbs the clogged surface layer of the sand. As has been repeatedly stated, air is drawn out of the water when passing through rapid sand filters, but the high velocities of flow of the water carry the air downward and out of the filter for the most part. This is one of the agencies which are instrumental in prolonging the runs between washings. Owing to the fact that the water is well coagulated before its application to the rapid sand filter, the particles of the sediment layer which ultimately pass further down into the sand bed are large enough to be caught and retained within the bed. The same would not be true of a slow sand filter operating on an uncoagulated water. Furthermore, it is permissible to allow a rapid sand filter to become clogged at great depth, because the whole bed is easily washed in place by a reverse current of water. In a slow sand filter the deep penetration of mud is not permissible, for such filters are cleaned by actually removing the sediment layer from the surface of the bed. If deep or uneven penetration of suspended matters into the bed occurs, it is necessary to remove a deep surface layer. This increases the cost of operation proportionately, and is by no means a small item in the total cost.

Slow Sand Filter Cleaning.

Water filters eventually become clogged by the foreign matters contained in the water applied to them, which accumulate on and

beneath the surface of the sand layer. Slow sand filters are ordinarily cleaned by scraping off the clogged surface layer, although attempts have been made to wash the beds somewhat after the manner followed in cleaning rapid sand filters. The best known among such attempts are the so-called "Brooklyn" and Blaisdell methods.

The former method was first used in 1905 at the Hempstead filter plant by the New York City Department of Water Supply, Gas, and Electricity. The plan involved what practically amounted to surface flushing, the clogged surface of the filter bed being raked over while a shallow stream of water was run over the surface by sections temporarily formed by boards set on edge and driven into the sand, thus forming a sort of flume having a width of about ten feet. After cleaning one section, the boards were moved to a new position. This scheme has been tried also at the Torresdale plant in Philadelphia, and elsewhere, but has not been very generally used.

The Blaisdell method involved the use of a machine which traveled on overhead tracks over the surface of the filters. This machine was first tried out at Yuma, Ariz., in 1902–03 and was given careful study at the Jerome Park test plant of the Water Department of New York City in 1907–08. A good descriptive article on the workings of this machine appeared in *Engineering News*, Vol. 59, No. 11, 1908, pp. 287, 288.

The Blaisdell sand washing machine consists of an inverted box about 4 ft. square and 2 ft. deep, containing a revolving hollow axle and a hollow head from which hollow teeth projected. In operation, the box is lowered in the water standing over the filter to the surface of the sand, and is held in position and operated from a platform above. By means of electrically driven mechanism the box can be lowered and raised and moved backward, forward, and sidewise at will. The box is made to slide over the surface of the sand at a speed of about 10 ft. per minute and at the same time the teeth are revolved, thus stirring the sand mechanically. Water is introduced into the hollow axle, head, and teeth under a pressure of 10 to 20 lb. to the square inch, and passes in fine streams into the sand. A suction pump connected with the top of the box draws away just a little more water than is

supplied through the teeth, and thus carries away and discharges to a sewer the dirt which has been stirred and washed from the sand. This method has been used in a few places but has not been generally adopted.

Another apparatus for cleaning slow sand filters is the Nichols separator, wherewith the dirty sand can be washed and restored to the bed without removing the scrapings to sand washers outside the filters.

Rapid Sand Filter Cleaning.

When the sand layer of a rapid sand filter becomes clogged, it is always cleaned in place by means of a current of water forced upward through the sand, the mud and other foreign matters which have accumulated in the bed being carried off to the sewer in gutters set near the surface of the sand layer. This has been standard procedure since this type of filter first came into use, and is one of its distinguishing features. The practice varies, however, with respect to the methods of agitating the sand layer during washing and the velocity at which the wash water is applied. This latter is governed particularly by the type of underdraining system provided. Filtered water is almost uniformly used in cleaning rapid sand filters.

In some of the early rapid sand filters, during washing operations compressed air was forced into the strainer system and escaped upward through the sand layer. This action served to loosen the bed, to break up the clogged sections, and separate the mud from the sand grains. The wash water which was next applied took up these foreign matters and carried them off to the sewer. In other filters wash water alone was used, the beds being cleaned by sections. In others (the majority of circular filters), the sand layer was stirred mechanically by rakes, while the wash water flowed upward through the bed and carried off the dirt at the surface. This is more common practice to-day in circular rapid sand filters. When the rectangular type of filter tank construction came into use in 1902 the strainer system was designed for the application of both compressed air and water, and more recently, due to the adaptation of underdraining systems of special design, the use of compressed air has been omitted and the beds cleaned by applying wash water at high velocities.

Low Velocity Filter Washing. Until the construction of the Cincinnati rapid sand filter plant, and excepting filters of the sectional wash type, rapid sand filters were always cleaned with wash water applied through the strainer system at a rate of about eight gallons per square foot per minute. This was the case whether or not any special measures were taken for agitating or stirring the sand while the wash water was being forced upward through it. Eight gallons per square foot per minute in a million-gallon filter unit corresponds to about 2 800 gal. per minute of wash water.

It was found in practice that such relatively low upward velocity of flow of water was not always sufficiently great to hold in suspension in the water above the sand and carry away to the sewer the heavy particles of mud and coagulated matter washed out of the filter. Violent agitation of the clogged filter bed prior to the application of wash water, such as that occasioned by the introduction of compressed air or the use of mechanical stirrers, served to break up the impurities within the bed into small particles, and these the wash water could carry out of the filter tank with relative ease. Even when compressed air was used to break up the bed, it was found in some cases that the subsequent addition of wash water at an upward velocity corresponding to eight gallons per square foot per minute did not always carry the impurities out of the bed, but allowed certain of the heavier particles to fall back on the sand layer, where they remained upon the surface, or sunk further into it. Particularly was this found to be a factor where the raw water was derived from swampy watersheds, and contained high amounts of dissolved color and suspended vegetable matter.

There seems to be no question about mechanical stirrers being the most effective means of agitating the sand in a circular filter. These stirrers, being kept in operation while the wash water is being applied, permit a speedy and thorough washing of a filter. Compressed air, on the other hand, cannot well be applied together with the wash water, since the whole bed of sand is kept in suspension in this manner and much of it may be lost by being carried off into the sewers with the wash water unless special sand-catching arrangements are installed over the wash water

gutters. The separate use of compressed air to break up the bed results in a satisfactory loosening action, breaks up clogged sections, and even effects some separation of the mud and other impurities from the sand grains themselves; but when the air is shut off, the heavier of these impurities fall back on the bed and have to be raised again by the inflowing wash water to the level of the wash water gutters, whence they may be carried out of the filter. While the separate use of compressed air and wash water applied at low velocity was the usual procedure with all filters of rectangular construction beginning in 1902, the feeling grew that perhaps something more than this combination was required, and thus developed the modern application of the high velocity wash idea, probably first practiced in the old type Hyatt filters of the sectional wash type over thirty years ago.

Filter Washing at High Velocity. In one of the early types of Hyatt filters the strainer system was laid out so that the bed could be washed in sections, the strainer manifold system and connecting piping being arranged so that wash water could be applied to one quarter of the filter bed area at one time. Hyatt could make use of high velocities in applying wash water to his sectional wash filters for the reason that there was no gravel layer immediately above the strainer system, the sand layer resting directly on the strainers themselves. Had the more modern type of construction been used wherein there is a shallow gravel layer separating the filter bed proper from the strainer system, the use of the high velocity wash would have resulted in unseating this gravel layer, which would then have become mixed with the sand layer, and this, of course, is not permissible.

The present type of New York sectional wash filter is an outgrowth of the original Hyatt sectional wash filter. As in their prototype of a generation ago, these filters are also arranged so that they can be washed in four sections, the supply of wash water being controlled by a valve centrally located. In a 15-ft. New York sectional wash filter, the filtering area is 176 sq. ft. Each quarter of the filter bed has an area of about 44 sq. ft. In washing filters of this type it is customary to supply wash water at the rate of 1 000 to 1 200 gal. per minute, this entire amount of water being discharged successively through the four sections.

When wash water is being used at the rate of 1 000 gal. per minute, applying this quantity of water over an area of 44 sq. ft. would correspond to a rate of wash water application of 22.7 gal. per minute per square foot of affected area. When the water is applied at the rate of 1 200 gal. per minute, this would be equivalent to a rate of $27\frac{1}{4}$ gal. per minute per square foot of affected bed area.

Cincinnati Practice. In 1903–05, when the Cincinnati filter plant was under construction, certain tests were made with an experimental filter, one of the principal objects of which was to determine the relative effect of the various methods of washing the sand and gravel of the filter bed. As a result of these experiments, which are fully detailed by J. W. Ellms in the Transactions of the American Society of Civil Engineers, Vol. LXXX, December, 1916, pp. 1342 *et seq.*, it was indicated that the most satisfactory method was that in which the wash water was forced up through the gravel and sand at such a rate that the sand was floated, thereby agitating and cleansing it in one operation.

In the Cincinnati filters, as is the case with practically all modern rapid sand filters of the rectangular type, the filter bed proper rests upon a layer of graded gravel, which in turn rests upon the strainer system proper. When wash water was applied at the strainer system under high velocity, difficulty was sometimes experienced through the unseating of the gravel layer, which thus became mixed with the sand layer above it. To obviate this undesirable feature, a screen separating the gravel and sand layers was installed in the Cincinnati filters. This screen held the gravel layer in place and made any mixing of the gravel with the sand layer impossible, no matter what velocity of entering wash water was used. This was by no means a new and novel arrangement, since the same idea was developed by John W. Hyatt in his cone valve strainer, which he covered by United States Patent No. 322,103. In this arrangement the strainer itself was filled with large shot, and this aided in the distribution of the wash water as it passed upward through it. The crown of the strainer was a perforated metal plate, and upon this plate the sand bed rested.

The essential purpose of providing a gravel layer between the

sand layer and the strainer system in any filter is to insure a more even distribution of wash water upward through the sand layer itself. This was attained by the Hyatt cone valve strainer, and the same thing was aimed at in the Cincinnati design, where the sand and gravel layers were kept apart by means of screens. This same general type of filter bottom was later adopted at Niagara Falls, Minneapolis, New Orleans, and elsewhere.

Later on, at Cincinnati, it was found that the screen separating the gravel and sand layers had pulled away from the bolts where it was attached to the ridges, and also at the ends of the tanks where there was lack of support for the wire cloth and insufficient means for fastening it. This discovery was followed by the removal of the screens separating the sand and the gravel and the use of deeper gravel layers. These gravel layers, some 14 in. deep, graded upward in size from 2-in. to ¼-in., afforded a protection against disturbances of the gravel through the application of wash water moving at high velocities and the subsequent mixing of the sand and gravel layers.

The Wheeler Filter Bottom. The next important development in a type of filter bottom which would allow of the application of wash water under high upward velocities without mixing the sand and gravel layers was the Wheeler filter bottom, which was patented by Mr. William Wheeler on August 24, 1915.

The Wheeler patent covers an arrangement of the filter floor into a series of cells, or depressions, these cells taking the form of inverted pyramids. In the lower end of each cell there is an opening. In each cell there is an assembly of pyramidally arranged spheres over the opening at the lower end. The apex sphere is heavy, is maintained in a fixed position over the opening in the bottom of the cell, and is so arranged as to receive the impact of an upward stream of water directly through the opening and distribute the same upward through the cell, compelling the passage of water between its outer surface and the walls of the cell. The apex sphere is substantially larger than the opening in the bottom of the pyramid cell, and overlies the major portion of the opening, but does not choke the outlet.

Over and about the apex sphere, and resting partly upon it and partly against the walls of the cell, are arranged four similar

spheres, and over these, and arranged in the same manner, are nine smaller spheres, all of the spheres being sufficiently large to provide water passages between them and the walls of the cell for effecting a uniform predetermined upward distribution of wash water to the filter bed above, and sufficiently heavy to remain substantially fixed against the upward flow of water past them.

In a recent article * Mr. Frank A. Barbour describes early experiences with the Wheeler bottom, and discusses in particular his observations respecting the installation at Akron, Ohio. Reciting the advantages of this type of filter bottom, Mr. Barbour lays especial stress upon its low first cost, the absence of dead spaces, the absence of metal parts subject to depreciation, and the completeness with which high wash water flows are distributed so that, with upward velocities as high as and even exceeding 4 ft. (30 gal. per square foot) per minute, there is no preceptible movement of a 6-in. gravel layer, even before the sand is placed. This gravel layer, it should be stated, consists of three layers, ranging in size from $\frac{3}{4}$ in. to about $\frac{1}{8}$ in.

A feature of interest in the operation of the Wheeler filter bottom is that the loss of head through the pyramidal pockets is less when all the concrete spheres are in place than when the pockets are empty. Experiments conducted in Jersey City by Mr. James E. Williamson disclosed as the probable reason for this the fact that, with the spheres in position, the center sphere, resting immediately above the discharge orifice at the apex of the depression, serves to increase the coefficient of discharge of the $\frac{3}{4}$-in. tube through the development of a vacuum at the point where the sphere rests on sides of the depression. Further experiments showed that when the rate of wash water application was 8 gal. per minute, the loss of head in the filter bottom, the 6-in. gravel layer and through the 30-in. sand layer, was 2.76 ft.; at 15 gal. per minute, 4.86 ft.; and at 22 gal., 7.80 ft. These figures are substantially the same as those reported for the remodeled Cincinnati filter. The greatest loss of head occurs in the strainer or floor system, the loss through the sand layer varying but little with the rate of application of wash water.

* Transactions of the American Society of Civil Engineers, Vol. LXXX, December, 1916, pp. 1411 *et seq.*

Essentials in Rapid Sand Filter Washing.

Whether low velocity washing coupled with air or mechanical agitation of the sand layer, or the application of wash water alone at high velocities is the better method, need not be discussed here. Perhaps in some localities one may be better than the other. There are certain essentials in rapid sand filter cleaning, however, which do not allow of argument. These are that, whatever the procedure followed, the gravel layer must not be unseated and mixed with the sand; the filter bed proper must be floated, and so broken up as to be amenable to thorough and economical washing; the upward flow of wash water must not be so great as to carry away with it appreciable quantities of the filter sand; and, finally, but by no means least, the foreign matters thus separated from the sand must be carried upward and out of the filter tank with the wash water.

Filter Cleaning Practice.

Violent air or mechanical agitation prior to the application of the wash water tends to thoroughly break up clogged sections of the bed and to comminute the particles of foreign matter separated from the sand. Thus the specific gravity of such matters is lessened and their flotation by the rising wash water which follows made easier. Application of wash water alone at high velocity may not break up these lumps of foreign matter into such fine particles, but the more rapidly rising column of water is expected to counteract this feature through its ability to float particles of relatively high specific gravity.

Until the rectangular filter tank came into use fifteen years ago, gravel layers, with a few exceptions, were not placed between the filter floor and the sand bed proper. The filter units were comparatively small, being seventeen feet in diameter or less. It is self-evident that to clean such filters thoroughly by applying compressed air, followed by wash water at low velocity, or by wash water alone at high velocity (sectional wash filters), or, as was the case in the majority of instances, by wash water at low velocity, the bed being stirred continuously with a rotating rake during the washing process, was not especially difficult. Circular filters

much larger than this present too many mechanical difficulties in the application of rake agitation, and out of this limitation, and a desire for space economy, grew the rectangular type of filter construction where units were built as large as 1 400 sq. ft. in filtering area.

The need of modifying existing methods of filter cleaning so as to obtain good results when washing these large rectangular units was at once apparent. Obviously mechanical rakes were not readily applicable to filters of this shape (the idea was tried without success at Louisville), and so recourse was had to the alternate use of compressed air and wash water, and later to water alone applied at high velocity.

In the early days, when only small plants of circular filters were being built, Hyatt's evident desire to overcome the necessity for mechanical agitators or even compressed air when washing filters took shape in his sectional wash filter. Careful scrutiny of his patent specifications leads to the conclusion that he was impressed by the fact that to apply the high velocity wash idea, by forcing large volumes of water through the entire filter, would lead to relatively, perhaps prohibitively, high construction costs for wash water pumps, pipes, etc.; and he aimed at securing the same result by applying wash water at high velocity to the filter bed in sections. In this way smaller pumps and discharge pipes could be employed, and in those early days a dollar to be spent for a water filter was scrutinized even more carefully than now, and that is saying a good deal. Naturally, then, the filter contractor sought every possible means of minimizing construction costs in order to make his proposition attractive. This was even more necessary then, when the filtration art was in its veriest infancy in this country, than now, when the beneficent record of water filtration is well understood.

As water filtration grew in popularity, large cities began to adopt it. Out of the demand for plants of large capacity grew the decision to build larger units. Reinforced concrete and rectangular filter tanks became the vogue, and with the construction of large plants the need of splitting hairs on the cost of wash water pumps, tanks, and delivery pipes passed into the discard. Filter floors were laid out for both compressed air and wash water application,

or for water alone, provision always being made for washing the entire bed at one time; and if the high velocity wash idea was adopted, the necessary means were provided.

Composition of the Little Falls Filters.

The 32-million gallon rapid sand filter plant built at Little Falls, N. J., was the forerunner of large water filters of reinforced concrete construction.* The filter tanks were built monolithic, in units 15 ft. by 24 ft., corresponding to a filtering area of 360 sq. ft. Each unit has a nominal capacity of one million gallons daily. The strainer system in each filter comprises a cast-iron header, oval in section, 12 by 6 in., running lengthwise of the tank in the center, to which are connected $1\frac{3}{4}$-in. cast-iron laterals, set $6\frac{3}{32}$ in. from center to center. The laterals are cemented into the header and extend to the sides of the tank, where their ends are closed with cement plugs. Into the header and the laterals are screwed strainers of the Continental type, on $6\frac{3}{4}$-in. centers. There are 1 316 strainers in each filter tank. Compressed air and water are applied through this single system of pipes, which are half embedded in the concrete floor of the filter tank.

The strainers are of brass, and in the top and sides thereof there are thirty-three $\frac{1}{16}$-in. perforations. The neck of the strainer is a $\frac{3}{8}$-in. brass tube, which extends into the cast-iron lateral to within $\frac{3}{4}$ in. of the bottom. This extension tube forms a trap when air is applied during filter washing operations, and the air passes from the lateral through a $\frac{3}{32}$-in. perforation in this extension tube, and located just below the upper wall of the cast-iron lateral.

The perforations in the strainers being somewhat larger than heretofore used, with the possible exception of the plants at Louisiana, Mo.; Middletown, N. Y.; and Cairo, Ill.,— where Mr. Robert E. Milligan initiated the idea of coarser strainers covered with gravel, — made necessary the placing of a layer of gravel over and around the strainers on which to support the sand layer and prevent it from reaching the orifices. The gravel layer in these

* "The Filtration Works of the East Jersey Water Company at Little Falls, N. J.," by George W. Fuller, Transactions of the American Society of Civil Engineers, Vol. L, p. 394, 1903.

filters is 7 in. thick and the sand layer 30 in. Gravel was selected of such hydraulic subsiding value that it would not be unseated when wash water was applied at a rate of about 7.5 gal. per square foot per minute, and of a size fine enough to prevent the sand from passing through the gravel layer.

The Little Falls plant served as the prototype for the majority of large filters built for several years after 1902, and then, perhaps as much to avoid the possibility of mixture of the sand and gravel layers during washing as for reasons of economy in construction, the now considered modern bottom, or filter floor, built in alternate ridges and furrows or as a checkerwork of square hopper-shaped depressions, made its appearance.

Development of Strainer Systems.

There probably has always existed in the minds of filter designers the conviction that the ideal filter is one which will allow wash water to be introduced at the bottom of the filter in such a manner as to insure an even upward rise over the entire horizontal plane of the filter, to avoid violent jet action, and particularly to avoid dead spaces at the bottom of the bed which the wash water would not directly reach in its upward flow through the filter. In addition to filter bottoms wherein the strainer system was arranged generally after the same fashion as in the Little Falls filters, there were numerous other types in which individual strainers played no part. Some early inventors devised filters with false bottoms, the upper sides of which were covered with perforated brass plates or wire cloth of fine mesh. Others laid out the filter floor in troughs covered with wire cloth or perforated plates, and in some filters the bottoms were composed of inverted cone-shaped depressions covered with perforated metal or wire cloth. In all such filter bottoms the perforated plates or wire cloth covering for the troughs or cone-shaped depressions were fastened flush with the filter floor, and upon this flat surface the sand bed rested.

Coincident with such designs as those just referred to were filter bottoms arranged in alternate ridges and furrows, the bottom of each furrow between two ridges being formed by perforated metal plates, sometimes two sets of such plates being fastened in the furrow, one above the other. The sand layer rested upon

these plates and upon the sloping sides of the ridges. The wash water passed upward through the perforated plates, and its flow being more or less obstructed by the filtering material was supposed to be made to flow in all directions so that, when it reached the top of the ridges, it thereafter rose through the filter bed evenly over a horizontal plane. Hyatt patented this idea in 1898.

A filter bottom somewhat similar to this, with the exception that the depressions instead of being continuous channels consisted of a checkerwork of pyramidal depressions, was built into the New Milford plant of the Hackensack Water Company in 1905. On each side of the central wash water trough, with a main effluent collector in the center, are four strainer and collector units. The lateral collectors are oval passages 4 in. wide and 5 in. high, formed in concrete blocks which are each 5 ft. by 8½ in. wide and 9 in. high. These blocks, when assembled side by side, form a strainer floor consisting of a checkerwork of hopper-shaped depressions 3 in. deep. The bottoms of these depressions are 3 in. square, and each supports a strainer consisting of a square plate of sheet brass perforated with 137 holes $\frac{1}{16}$ in. in diameter and pressed into the form of a flat truncated pyramid. Below the strainer is a pocket about 2½ in. square, connected with the lateral collector by a piece of $\frac{3}{8}$-in. brass pipe. The strainer is fastened down with a $\frac{1}{8}$-in. brass bolt, screwed into a brass nut, set in the concrete at the bottom of the pocket. Each of the eight units of the strainer system has a central main collector to which the oval laterals connect.

The next step was to lay off the floor of the filters in ridges and furrows, the furrows being filled with gravel and arched over from ridge to ridge with wire cloth. This was the first definite step toward the modern application on a large scale of Hyatt's idea, disclosed in his sectional wash filter, patented in 1898. It was thought that the channels with sloping sides when filled with gravel would eliminate dead spaces which the wash water could not directly reach in its upward passage through the filter bed, and thus produce an even distribution of the wash water over all parts of the filter; and the screen separating the gravel from the sand would surely guard against any possibility of their becoming mixed. City filters constructed at Cincinnati, New

Orleans, Louisville, Minneapolis, Grand Rapids, Evanston, and elsewhere, between 1906 and 1914, had bottoms of this type. It is furthermore worthy of note that some years ago Mr. Ira H. Jewell brought suit against the city of Minneapolis, claiming infringement of certain patents owned by him, among these being Patent No. 649,411. In August, 1915, the United States District Court decided that the brass wire screen, such as above described, infringes Claim No. 14 of Patent No. 649,411. On appeal, however, Judge William C. Hook, of the Circuit Court of Appeals, handed down a decision in St. Paul on October 16, 1916, reversing the findings of the lower court and directing that the suit should be dismissed.

The next step and latest development of filter floor design was the Wheeler bottom, first installed in a filter of size at Akron, Ohio, in 1916.

In washing a rapid sand filter of whatever design, it is imperative that the operation be so conducted that the gravel and sand layers will not become mixed to any material extent, for reasons that are obvious. The Wheeler bottom probably comes nearer being a perfect safeguard in this respect than any type of filter floor yet devised. The filter bed must be floated, and so broken up, thus aiding in a most substantial manner the thorough and economical washing operation. When a rapid sand filter has been in operation several hours it is closely compacted and hard. It cannot be efficiently cleaned until it is well loosened and all lumps broken up. It is important that the upward velocity of the wash water be not so great as to carry appreciable amounts of sand out of the filter. Provision against this is best made by the judicious arrangement of wash water gutters, bearing in mind that a bed of sand having an effective size of .40 mm. and a uniformity coefficient of about 1.60 will rise about 8 in. when wash water is being applied at a rate of about 7.5 gal. per square foot per minute; about 12½ in. with 15 gal. per minute, and about 16½ in. with 22 gal. per minute.

Rate Control.

One of the cardinal necessities in filter operation is the control of the rate of passage of water through the filter. Slight varia-

tions are permissible, say within 5 per cent. limits, but sudden fluctuations much greater than this have a marked disturbing influence on the condition of the filter bed and the quality of the filtered water. Gradual variations in the rate of filtration, if relatively small, are of practically no significance, except, perhaps, where a material reduction in the velocity of flow of water will sometimes allow occluded air to pass upward and break through the most effective part of the filter bed, namely, the *schmutzdecke*, or mud layer on the surface of a slow sand filter, and the clogged stratum in the rapid sand filter. The greatest danger accompanying sudden increases in the rate of filtration lies in the shock to which the filter is subjected. The natural clogging of a water filter takes place gradually, and where the rate is practically constant the frictional resistance to the flow of water through the filter builds up proportionally. A sudden increase in the velocity of flow through the filter, caused by quickly opening the outlet, will break the filter and carry the foreign matters deep into the sand, and even completely through it. The normal functions of the filter are thereby temporarily upset, and under these circumstances the quality of the filtered product suffers marked deterioration. One would never consider it proper to increase the speed of a pump by suddenly opening the throttle. The strain would tend to injure the pump and perhaps destroy it. Suddenly increasing the rate of filtration in a filter will just as certainly be followed by unsatisfactory results.

In the early days such attempts as were made to regulate the rate of filtration were effected by hand regulation of the effluent valve.

The automatic filter controller, designed by Mr. Edmund B. Weston in 1899, was the first to justify recognition as an effective safeguard against rate fluctation, and is used successfully in a very large number of filter plants. It is a device wherein the velocity head, or an artificially created difference in head in the effluent pipe, regulates proportionately the area of a discharge orifice. There are several automatic rate controllers of the Venturi type which are widely used. A Venturi tube is placed in the effluent pipe, and beyond this is a valve whose opening is regulated by the position of a piston contained in a cylinder. A pipe connection

from the Venturi throat transmits the pressure at that point to the upper side of the piston. The underside of the piston is subject to the pressure in the pipe beyond the Venturi throat. By shifting a counterweight on a lever attached to the piston the resistance at the valve is increased or lessened as the case may be, and the flow consequently increases or decreases until a balanced condition is restored.

Red Water Troubles.

A phenomenon not infrequently encountered where a community changes from an unfiltered to a filtered supply is the appearance of iron rust in the water. Until the matter was given particular study, the use of alum salts in the purification process was thought to be responsible for this, the chemical compounds resulting from the decomposition of aluminum sulphate in water acting as corrosive agents on iron service pipes. If alum is used in excessive amounts, that is, in quantities which cannot be decomposed by the natural alkaline constituents of the water, or by alkalies artificially added to the water, — and free alum passes into the filtered water, rendering it acid,— then there is no question that such a water will exercise a corrosive action on service pipes; but where the coagulating chemical is used as it should be used, and always can be used, the employment of aluminum sulphate in water purification processes is of no significance with respect to the production of " red water " through the passing into solution of iron from pipes, with the possible exception of the added encouragement to corrosion afforded by the small amounts of free carbonic acid liberated from the coagulating chemical when decomposed in water. And even this feature can easily be nullified, practically speaking, through aëration of the filtered water.

Omitting the purely technical side of the question of metal corrosion by water,* it is well known that iron has a natural tendency to dissolve in water. Whipple (*loc. cit.*) classifies the water supplies with which red water troubles have been observed, as follows:

* In this connection the reader is referred to the following publications and to the references given therein: W. H. Walker, *Journal Boston Society of Arts*, January, 1909; G. C. Whipple, Proceedings American Water Works Assn., 1911, p. 231; R. S. Weston, Journal N. E. W. W. A., Vol. XXIX, p. 559.

Class 1. Very soft waters.

Class 2. Waters in which chlorides or the free carbonic acid are high as compared with the alkalinity.

Class 3. Very soft surface waters that are relatively high in color and contain peaty organic matter and free carbonic acid.

Class 4. Relatively soft waters, especially high-colored waters, with which sulphate of alumina is used as coagulant, but which are not overdosed so far as the alkalinity is concerned.

Class 5. Waters overdosed with sulphate of alumina so as to render them acid.

Class 6. Waters containing originally excessive amounts of iron.

The waters of Class 1 contain high amounts of free carbonic acid, often are high in chlorine, and contain considerable iron in solution. Aëration and filtration will correct the iron defects in such waters and eliminate red water troubles through dissipation of the free carbonic acid and oxidation of the dissolved iron.

Waters of the second class are found along the Atlantic coast, and also where natural salt deposits obtain. The high chlorides in such waters play an important part in metal corrosion, and they cannot be removed from water by any practical method.

Waters containing originally high amounts of iron (Class 6) can be corrected by aëration and filtration, and red water troubles due to the precipitation of the iron in pipes and domestic containers be thus nullified.

Waters which have been overdosed with aluminum sulphate so as to render them acid need no discussion. They will corrode metals and cause red water trouble, but there is absolutely no excuse for such overdosing. With a competent filter operator such a thing would not occur.

We now come finally to the waters of Class 3 and Class 4. These waters are fairly soft, contain considerable vegetable stain and peaty organic matter picked up on the watershed, and are usually high in free carbonic acid. It is desirable to decolorize such waters, and the only practical manner in which this can be done is by coagulation and filtration.

It is perfectly well known that carbonic acid dissolved in water increases the hydrogen ions present and consequently increases

its corrosive properties. The waters of the two classes under discussion naturally contain relatively high amounts of carbonic acid. The Passaic River above Little Falls contains as high as 15 parts per million, and averages 8 parts per million. Other river and lake waters draining similar watersheds contain even more free carbonic acid than the Passaic River.

Now when such waters are treated with aluminum sulphate to prepare them for filtration the natural free carbonic acid content is increased by some four parts per million to each grain per gallon of added coagulant. Doubtless this is a factor in some places in increasing the corrosive properties of the water, but an efficient remedy lies in the aëration of the filtered water whereby the bulk of all the free carbonic acid is dispelled from it. If the case is serious, the addition of alkalies will entirely eliminate the free carbonic acid, but it is a much less satisfactory remedy than aëration.

Water highly colored with vegetable stain is high in organic matter, and the removal of this organic matter by filtration unquestionably is one of the chief causes, if not indeed the leading, of increased corrosion of metals, and a contributing factor of major importance in the causation of red water troubles. Any kind of a filter which removes this organic matter, whether or not aluminum sulphate is used with it, will yield an effluent which may be criticized on this score, for this very organic matter gathers on metal surfaces and thus forms a protective coating. There are experiences on record at variance with this viewpoint, however. The Charleston, S. C., water, drawn from a swampy watershed, was highly corrosive before filtration, according to Mr. J. W. Ledoux.* After rapid sand filtration, whereby most of the organic matter was removed, the corrosive effect was reduced to a minimum.

Organic acids in waters of this character may play some part in metal corrosion, but how far the acid character of such waters is due to carbonic acid, and how far to the but indifferently understood group of complex organic compounds, is by no means plain.

In a discussion of red water troubles one necessarily is confronted with an almost uninterrupted chain of conflicting evidence.

* *Engineering Record*, Vol. 60, p. 701.

It is probable, however, that a prime contributing factor is the lack of care with which metals are selected in building a water distributing system, and lack of attention given to artificial protective coatings. This must be so, else there would not be the common occurrence of red water on one street and none on another; in one house and not in the next. Weston (*loc. cit.*) has well said:

"If a water contain dissolved salts, even though alkaline, homogeneous metals should be used in contact with it. The insides of meters, valves, and pipes, wherever possible, should be of such a composition that electric currents will not be generated."

So far as affording a fulcrum on which to force an argument against rapid sand filters, or filters of the slow sand type where coagulants are often used, the evidence is weak and unreliable that red water troubles are due to the use of aluminum sulphate as a coagulant. The waters most liable to attack metals are pure waters containing large amounts of carbonic acid and oxygen. Filtered waters are pure waters and not infrequently contain high amounts of free carbonic acid as discharged from the filters. Aëration will remove this for the most part, and in the design of filter plants for the treatment of colored waters drawn from swampy watersheds particular attention should always be given to this feature,—far more attention, in fact, than has been devoted to it in the past.

Local Manufacture of Aluminum Sulphate.

Until quite recently, water purification works were obliged to depend on the open market for their alum. Within the last two years a process has been perfected whereby filter alum can be made readily and cheaply by the individual consumer. This is known as the Hoover Process, and was worked out by Charles P. Hoover, chemist in charge of the water purification plant at Columbus, Ohio, and on September 5, 1916, United States Patent No. 1,197,123, covering the process, was issued to Mr. Hoover.

The process itself is very simple. The raw materials are commercial sulphuric acid and low-grade bauxite ore. To make alum, two parts by weight of acid and one part of pulverized bauxite are brought together and thoroughly mixed. The mixture is

then discharged into a shallow pan or box. The reactions which ensue take place naturally, the water of crystallization is driven off and the cake hardens. It is removed from the box in lumps, and these lumps are thereafter used in preparing coagulant solutions in the same manner as when the ordinary market alum is being used.

For a plant capable of turning out a ton of alum per day, a space about 15 ft. by 25 ft. by 10 ft. high is required. Storage space for acid and bauxite is needed. No artificial heat is required at any stage of the process, and no labor other than to proportion the raw materials, supervise their mixture, discharge the mixture into the crystallizing boxes, and later remove the hardened cake. Mixing may be made easier by utilizing a small motor. About ten minutes is required to get a satisfactory mix. The simplicity of the whole procedure may be gathered from the mere statement that to make alum by the Hoover process one needs but to mix thoroughly two parts of sulphuric acid and one part of pulverized bauxite in a bucket and allow it to stand. A few hours later a cake of alum is found at the bottom of the bucket.

The alum produced by the Hoover process is a basic aluminum sulphate which is even more effective per unit of weight than the ordinary commercial aluminum sulphate purchased in the open market.

When the use of alum for water purification purposes began to spread, some thirty odd years ago, the users first turned to potash alum and later to aluminum sulphate. These chemicals had heretofore been used in paper making and other industries where a particularly pure article was required. The water filtration man immediately jumped to the conclusion that he needed just as pure a product, and was satisfied to pay a high price for a refined alum which actually, for his purpose, had had removed from it in the process of preparation a substantial amount of the active coagulating constituents.

Mr. Hoover's process does not include the filtration of the liquid chemical before crystallization, consequently none of the aluminum sulphate and basic iron and aluminum is thus lost as it is in the market alum. In the ordinary alum sludge, removed with the insoluble matter by such filtration, there is contained

some 3 to 4 per cent. of available alumina. This is retained in the Hoover alum, and lost in the regular market alum.

Hoover alum, not being filtered, contains from 7 to 10 per cent. of finely divided, insoluble, suspended matter. This suspended matter, instead of proving a nuisance, by virtue of its very fine state of subdivision serves as a nucleus around which the gathering floc can form. Actual experiments with Hoover alum and several well-known brands of regular market alum, viewed by disinterested parties, showed that, unit for unit of weight, the Hoover alum possessed the greatest coagulating powers.

But little can be said at this time about the cost of making alum by the Hoover process, since the acid market is in such an uncertain state. Roughly speaking, however, 60-degree Beaume sulphuric acid may be bought at this date for about $20 per ton, f. o. b. point of manufacture. Pulverized bauxite costs about $15 per ton, f. o. b. Bauxite, Ark. For raw materials to make a ton of 17 per cent. aluminum sulphate the cost would therefore be about $19 plus freight. In New England, the total cost of raw materials for a ton of alum would be about $25. Labor, repairs, and other incidental charges would add about $2 or less, so that at present the total cost per ton of manufacturing alum by this process would be around $27. Regular market alum containing 17 per cent. available alumina is now quoted at about $40 per ton, f. o. b. point of manufacture, and the prospects are that it will shortly go to $60 per ton.

Cities now using the Hoover process are Springfield, Mass.; Trenton, N. J.; Cumberland, Md.; Columbus, Ohio; Omaha, Neb.; and Montreal, Quebec, and a plant for making 1 500 tons of alum annually is now being built at Little Falls, N. J., by the Montclair Water Company. A good illustrated review of the experience with this process by the various filter plant superintendents in the above-mentioned cities is contained in *Engineering News*, Vol. 77, Nos. 1 and 2, Jan. 4, 11, 1917, under the caption, "Five Water-Works Make Alum."

Sterilization.

Not much need be said about water sterilization, for so much has been written regarding it in recent years that its advantages

in practically all water purification problems are well understood. Even though the continuous use of sterilizing agents in water purification began less than nine years ago, the practice has spread until, in practically all up-to-date water purification plants in this country, sterilization is an integral part of the system. Hypochlorite of lime has been supplanted in many places by chlorine gas, and sterilization by the ultraviolet ray process has been adopted in quite a number of places, the most recent relatively large installation being that at the Henderson, Ky., water works. During a somewhat protracted and carefully conducted test of that plant in March and April of this year, when about 3 000 000 gal. of water were being treated daily, after passing five lamps the filtered water contained on an average less than one bacterium of any kind, and bacteria of objectionable types were uniformly and thoroughly killed at all times.

Hypochlorite of lime solutions are not so easy to handle as chlorine gas, but continue to give good results. Chlorine gas application also requires attention, since the orifices become clogged at times with foreign matters. In the ultraviolet ray process the lamps must be watched and the current consumption kept under observation. None of these sterilizing processes is entirely automatic in its action, and all are subject to human control if consistently good results are to be obtained.

Both hypochlorite of lime and chlorine gas are unsuccessful in the complete destruction of spore-forming bacteria. For example, in Jersey City this year, during an intensive study of the character of the water supply of that city, when hypochlorite was being added to the water in quantities ranging from 0.63 to 0.91 part per million available chlorine (the upper amount being all the water could stand without producing in the water an objectionable taste of the chemical), the presumptive B. coli record of the water delivered in Jersey City was such as to pass the United States Treasury Department limit of two B. coli per 100 cc. only on ten days in the entire period of the investigation covering the months of March, April, and May. This unsatisfactory B. coli record, as proved by confirmatory tests, was caused by the presence in the water of B. welchii. These organisms, themselves of fecal origin and an index of fecal pollution, form spores which

could not be eliminated by chlorination applied within the limits possible without imparting to the water objectionable tastes and odors of the chemical. Tests which the author has made with the ultraviolet ray process showed that spore-forming bacteria are killed by it with comparative ease. Even the hardy paramæcia are killed in water by a few seconds' exposure to ultraviolet rays.

Comparing the relative merits of chlorination and the ultraviolet ray process of water sterilization, and eliminating questions of cost, it may be said that if a perfect sterilizing score is to be recorded, the water to be sterilized must be free of suspended matter. Unfiltered waters containing suspended matters, particularly where such matters are organic in character, may be sterilized with a fair degree of success by either chlorination or the ultraviolet ray process; but these suspended particles serve as admirable hiding places for bacteria, and embedded in such particles disease bacteria will remain unkilled, to pass on to the ultimate consumer. Entirely satisfactory results are obtained only when waters are filtered and freed of their suspended matters prior to sterilization.

The ultraviolet ray process possesses two advantages over chlorination. In sterilization by chlorination the chemical or gas is customarily added at a single point. In the ultraviolet ray process the water is made to pass by a succession of lamps. If the first lamp does not destroy all of the objectionable bacteria, that work is left to succeeding lamps until the desired result has been obtained. With chlorination there is a limit which one may not exceed as regards the size of the dose without imparting to the water offensive tastes and odors of the chemical. With the ultraviolet ray process, overtreatment cannot impart offensive tastes and odors to water, since nothing enters it but the invisible ultraviolet rays.

Pressure Filters.

Pressure filters of the rapid sand type are now operating on municipal supplies in this country in 140 places with a present total population estimated at 1 946 000. The combined capacity of these 140 plants is 257 200 000 gal. daily. The individual

plants range in size from 100 000 gal. daily up to the 21 000 000-gal. plant at Atlanta, Ga.

Pressure filter plants, therefore, constitute 20.5 per cent. of the total number of municipal rapid sand filter plants in the United States, 10.8 per cent. of the total filtering capacity, and serve 10.6 per cent. of the total population served.

It is not considered necessary in this paper to discuss at length the relative advantages of gravity and pressure filters. A recent article on the subject,* and the discussions accompanying it, cover the matter in a quite thorough fashion.

The first rapid sand filters installed in this country for the purification of municipal water supplies were of the pressure type, and in the growth of the filtration art such shortcomings as these earliest filters possessed have been handed down and accepted by some as inherent defects in the process. The first pressure filter plants were without adequate facilities for proportional chemical application, and rate control was a matter to be governed by the demand for water. The same history can be recorded for the gravity filter, but the latter is capable of greater elasticity in individual design, and consequently it was favored in the development of new ideas.

The pressure filter was, and still largely is, of stereotyped design. It was considered by many to be automatic in its action and to need no attention or control other than cleaning when it became clogged and failed to yield enough water. The model pressure filter of to-day can be fitted with rate controllers and devices for accurately proportioning the dose of coagulant. Everything that can advantageously be built into a gravity filter system is equally applicable in a pressure filter system.

The pressure filter is particularly adapted to water problems where double pumping is an important item of expense, since with this type of filter one pumping may be avoided. Along the general line of filter-operating economy it is significant that the pressure filter is looked upon with considerable favor by private interests. Of all the pressure filter plants operating on municipal supplies in this country, over one third are owned by private

* "Pressure Filters," by Harold C. Stevens, *Journal of the American Water Works Association*, Vol. 3, Nos. 2 and 3, 1916.

companies. Such companies certainly operate their properties as economically as possible, the first thought of the business man naturally being to furnish satisfactory service at the lowest possible cost. Such operators of pressure filter plants evidently are able to secure good service for less money than would be possible with gravity filters.

Since water sterilization gained an accredited standing, the requirements of water filters, *per se*, have been altered materially. With the realization that cheap and efficient means had been found whereby dangerous bacteria in water could be readily killed, the necessity of relying upon the filter itself for high efficiency in this respect passed away. The filter is still needed to remove color and turbidity, but sterilization of the physically satisfactory water may be relied upon to insure the performance of the really consequential phase of the bacterial side of the purification process.

To those who perhaps would prefer to use pressure filters, this point is one of much significance. Probably not a few places have adopted gravity filters because they feared the pressure filter would not give the required high bacterial efficiency. When this doubt now arises it is answered in a satisfactory manner by sterilization. A properly equipped pressure filter plant, efficiently operated, will yield just as good appearing an effluent as a gravity filter, and any dangerous bacteria which may escape from this or any other filter can be killed by sterilization.

Discussion.

Mr. L. M. Hastings.* This subject is of vital interest to every one who has charge of water works, and especially those who have surface water supplies. Nearly all of us have suffered more or less from color and taste of the water, and, as Mr. Johnson and others have said, the only remedy seems to be either filtration or sterilization. Now, when you introduce alum or chlorine, there is always a feeling in the popular mind that there is a taste left in the water unless the operation is very carefully conducted. I suppose it would be very difficult to satisfy the

*City Engineer, Cambridge, Mass.

public generally that there is not some taste remaining in treated water. I should like to ask Mr. Johnson whether there was any special method of treating, other than what he mentioned of using care to avoid over-dosing, so that the peculiar taste of the chemical might not remain. I suppose, after one case of over-dosing, the people who got that taste will never forget it and will always say, " Well, your filtered water is all right, but it tastes."

Now, after we have treated our water and got it pure and sterile at the filters, what is its condition after passing through dirty and foul pipe? I should like to ask Mr. Johnson whether there are any data showing how necessary it is, how frequently — where chemically treated water is used — it has been found necessary to wash out the distribution pipes. Any one can see that, no matter how pure and clear the water is, by passing it through 100, 150, or 200 miles of foul, contaminated pipe, you are likely to get an unsatisfactory result.

The next question relates to wash-water. Take a case of a system that is pretty near to its limit of capacity. The reduction of the available supply by abstracting 2 to 7 or 8 per cent. of the water for washing purposes and then running that away to the sewers seems an important matter. And it seems as though it would be practicable to recover that water, or a considerable proportion of it. After it had been used once, if you could then wash the water again and use it there would be a great saving. Whether that is practicable or not I don't know.

Mr. Johnson. There is not any question that the bad name that alum got in the early years of water filtration was due to the use of the old-fashioned alum pot in connection with the pressure filter. In those days there was very little attention given to the proportion of the coagulating chemicals with the raw water; but in the past twenty years precise devices have been invented and put into practical service which render it easy to get an exact adjustment of the coagulating chemicals at all times. There is no excuse whatever in any plant operated by an intelligent filter operator of ever getting an overdose of alum. We all know that the dose of chemical is adjusted according to the physical imperfections of the water. If the natural alkaline content of the water is not sufficiently great to thoroughly decompose all of the

coagulating chemicals, — that is, to effect adequate coagulation, — then the practice is to apply artificial alkalies, like soda ash or lime, to make up this deficiency and prevent any undecomposed alum passing into the plant. There is not any question either that in a great many cases the people think they can taste alum in the water long before the alum is ever applied to it. That has been learned in a number of cases. You don't have to have the alum in the water so long as they can taste it. But in these days we don't give any concern at all to the possibility of undecomposed alum going through the filter plant. That is under such good control now that it is no longer considered to be even a possibility with efficient operation. But it is like other things, it is subject to human control, and sometimes of course it might fail, although it never has in my experience.

Now, in reference to the cleaning of mains following the construction of a filter plant, I think the usual custom is to give them a good thorough blowing-out, and that is about all. Of course, if there has been an epidemic just prior to the installation of the filter plant, it is not unusual to treat the water in the mains with a heavy dose of germicide. I think one of the first cases on record was at Lincoln, England, where they had an epidemic of typhoid fever, which was followed by an intensive sterilization of the water in the mains. It is rather a peculiar thing in this connection that when a filter plant is turned into service its effect is immediately noted even though there may not be any particular effort made to clean out the pipes. I have one particular case in mind, — that at Norfolk, Va., where some eighteen or more years ago that plan was put into operation. The newspapers the next morning came out with large headlines to the effect that it was easily seen that the water had been given a bath. It changed from a dark amber color to a clear, colorless water. And there was no special effort made to flush out the pipes. In time the system will probably clean itself.

As to the utilization of wash water, I know Mr. Hastings refers to his own problem in Cambridge. The possibility was considered very carefully there of conserving the wash water by discharging that wash water into a storage tank where it would be allowed to settle and then be pumped back into the settling basin;

or to catch it in this basin and pump it back without sedimentation and thereby conserve the entire water that was used for washing the filters — simply use it over and over again. There seems to be no objection to that.

MR. R. S. WESTON. I might say for Mr. Hastings' information that the conservation of wash water has been practiced in one case I know of, where the wash water was discharged into the pond and the clarified water pumped back into the basin. At Baltimore they provide a large pond for the clarification of the wash water, and that water is surprisingly good. It can be used over again much better than the raw water.

MR. W. C. HAWLEY.* When our new filter plant was built, the saving of the wash water was considered, and they built a small tank into which the wash water was discharged, and after five or six hours' sedimentation the water is pumped back into the settling basin. The analysis of that water showed that the settled water is better water than the raw water coming to the basin. Our total loss of wash water is only about one tenth of one per cent. We are pumping our water against a head of about 630 feet, and that of course makes it desirable to conserve that water.

MR. R. E. WISE. I would like to ask Mr. Johnson what color the public is satisfied with in the filtered water, — that is, whether they would be satisfied with 15 or 20, or what is the general rule?

MR. JOHNSON. I believe that water should not contain more than 10 parts color, although you can get by with 15 parts. Water with more than 10 parts color to the million will show up badly in a bath tub.

MR. WILLIAM JAY WILLSON. I would like to ask Mr. Johnson if he has any data which will show what per cent. of water works with filter plants produce water with a color of less than 12 parts to the million.

MR. JOHNSON. I think it can be said almost without reservation that in the vast majority of filter plants either of the slow sand or the rapid sand type, wherein a coagulating chemical is used, the average color of the effluent will be less than 10, although there are cases that I know of — Springfield is one of them —

* Wilkinsburg, Pa.

where it is not considered necessary to get down to that fine point.

MR. ELBERT E. LOCHRIDGE. On the question of clearing out the system when filtered water is applied, I would like to say that in Springfield we did do this. The object of this clearing, however, was a little differeht. Bringing in the new supply from the west, while the old came in from the east, changed the direction of flow through a great many of the pipes, and for the purpose of removing material, or the rust or sediment which had collected in the pipes, each street was figured to get a 9-foot velocity, and hydrants or other openings sufficient for this were opened. This 9-foot velocity in the pipe will take almost everything there is in the pipe out. And we have found that that has been beneficial. On the other hand, it is not necessary. Your improvement in water from filtration will come at once, and it should be remembered that the sediment which forms in pipes is something which the condition in the pipes allows to settle there or to form there, and there is not a tendency, unless that condition is changed, to again pick that material up in the normal use of those pipes.

Taking Mr. Johnson's point of color — I am not inclined to quarrel with him as to what is the proper color, but he has referred to the fact that we consider 15 or 17 or 20 sufficient in Springfield. I think this is a good deal a matter of the condition of the individual case. If you are able to get a water with reasonable treatment, which, with the small alkalinity which you have can always be obtained at the point at which it would be thoroughly stable, and if that water is satisfactory on the table, always clear, you have reached one of the main points which govern what that color should be. I find that a city which is perfectly satisfied with a color of 30 or 40 when it is not filtered, after they have had filtered water for awhile they are not satisfied with 25. If you give them 15 for awhile, they will want 15; they will not be satisfied with 20. But I have not been able to determine that there has been any appreciable demand for a color of 10 if you are giving them 15. I suppose if we educate them farther they will demand water of 5, and after that we will have to go farther yet. But a water which does not show color in a glass on the table does not call attention by its color to its presence, and

that is one of the main features for determining the color, which should be under 20. And I believe there are thoroughly satisfactory waters with colors above 20.

MR. J. S. DUNWOODY. The subject of Mr. Johnson's paper is of vital importance to engineers and water-works superintendents, especially if they are anticipating the construction of filter plants. And as Mr. Johnson has mentioned the Erie case and given a description of the false bottom strainer system, I might add a few words, after a few years of operation of this Erie plant, about the results we have obtained there in our false bottom strainer system. The plant completed its third year of operation the 1st of July of this year. At that time we had not had one bit of trouble of any kind in regard to our strainer system or our false bottom system. Of course, the life of this false bottom we are not able to state inside of three years, although these false bottoms have been carefully inspected every year, and while they are covered with barnacles, there is no indication that these barnacles are having a serious effect. The strainer system has never given any indication of plugging, and we have had no trouble with the water. We have a very even bed throughout the entire area, using a wash of about 10 gallons per square foot per minute. While the plant was designed for a heavier wash than that, we found we got a very heavy wash at 10 and use the 10-gallon wash about eleven months out of the twelve. During a period of two weeks in the spring and fall we increase the wash slightly. This system of strainer false bottoms in Erie has been a very great success and has given no trouble at all.

MECHANICAL FILTER BOTTOMS AND STRAINER SYSTEMS.

BY ROBERT SPURR WESTON, C.E., BOSTON, MASS.

[*Read September 12, 1917.*]

It is unnecessary to recall to your minds that the strainer system of the mechanical filter, unlike that of a sand filter, serves two purposes, namely, it must collect filtered water from the sand and must serve as a distributing medium for the wash water used for washing. Unfortunately, the velocity during washing may be more than five times the velocity during filtration, and this, of course, introduces great difficulties in design; for it is essential that the rate of filtration be uniform throughout the whole sand layer, and that the wash water be distributed as uniformly as practicable over the whole filter area so that it may rise as a plane or sheet for the purpose of separating the accumulated coagulant and fine suspended matter without at the same time causing any considerable loss of sand.

As many will remember, the simplest and perhaps the earliest form of strainer system was a perforated metal plate. This is used no longer except for small filters. The next step in advance was to screw strainers or "sand valves" directly into the perforated metal plate. There have been many kinds of strainers. The early ones were made of fine, perforated metal or wire cloth supported by a suitable brass casting. Later strainers were provided with drilled or punched holes or sawn slots. Most of the openings in these earlier strainers had a diameter or width of less than 0.1 mm.

In the earlier filters the sand rested directly upon the strainers, with the result that the fine perforations clogged quickly, making extensive and frequent repairs necessary. The remedy was to enlarge the perforations in the strainer and to place above the same a layer of graded gravel about six inches in thickness. This prevented the sand from reaching the strainer, and clogging did

not occur. About the same time it was found that in the space below the false bottom the velocities of flow were so low that sand and coagulated matter accumulated, thereby furnishing a pabulum for the growth of bacteria. Therefore, notwithstanding the fact that the false-bottom type of filter was ideal for the distribution of wash water, a pipe manifold was substituted for the false bottom in order to maintain higher velocities in the underdrains.

The early filters were circular, and were equipped with revolving rakes to agitate the sand during washing. Wash-water velocities of less than one vertical foot per minute were used. Later (about 1893) the air agitation system was introduced by the Continental Filter Company, thus permitting rectangular construction and concrete filters. The rakes were abandoned soon after.

The Little Falls plant, put in operation in 1902, typifies the best practice of the time. The strainer consisted of a perforated metal cap attached to a threaded fitting from which a small tube depended. In one side of this tube, near the fitting, was a small hole through which air passed for the purpose of agitating the sand layer. The dependent tube formed a trap so that the strainer could be used for both air agitation and wash-water distribution. This strainer system has been fairly successful, although hard spots occur in the filter from time to time, and special cleanings of the filtering material have to be made. Low wash-water velocities were employed, and air agitation was necessary.

The next large filter plant to be built was the one at Cincinnati, which was put in operation in 1907. This marked a new departure in that air agitation was done away with and a wash-water velocity of 22 vertical inches per minute was found to be necessary for the perfect cleansing of the sand. The strainer system consisted of perforated plates covering concrete channels located at the bottom of trough-like depressions running lengthwise of the filter. This bottom is illustrated in Flinn's "Handbook" and described in Ellms's new book on "Water Purification." The trough-like depressions were filled with gravel, and, to prevent its displacement during washing, wire-cloth screens were bolted to the tops of the troughs. These retained the gravel effectively and prevented the passage of sand into the filters, but it has been found

that they corrode rapidly in certain waters, notably at Cincinnati, and recently they have been removed and the necessity for their use avoided by increasing the depth of gravel above the strainers to 14 inches.

The Cincinnati type of filter bottom, while efficient, is quite expensive, and the next step was to secure the same results for a lower cost. The strainer system used at Harrisburg, Pa., consisted of a pipe manifold on the under side of which holes were drilled. The pipes composing the manifold were $1\frac{1}{4}$ in. in diameter, laid 6 in. apart, and drilled with $\frac{7}{32}$-in. holes spaced 3 in. center to center. In this filter, air was used for agitation. Somewhat later, filter bottoms of the Harrisburg type, in which the use of air was omitted, the velocity of wash water increased, and the gravel layer deepened to 14 in. or more, were used, probably first by Philip Burgess, C.E., of Columbus, Ohio. A similar form used at Toledo and Youngstown, Ohio, both of which plants were built by the Norwood Engineering Company, consists of the ordinary pipe manifold into which star-shaped strainers of the Norwood type were screwed. The Norwood Engineering Company has always believed in air agitation, and all of their filters are constructed with this end in view. Nevertheless, there is no reason why this type of filter bottom may not be used without air agitation, provided the strainer openings are enlarged, the gravel layer deepened, and the wash-water velocities increased to the optimum for the sand employed.

The next improvement was the so-called Wheeler filter bottom, consisting of inverted pyramids filled with spheres covered with a layer of gravel 6 to 8 in. in thickness. A series of channels corresponding to the pipe manifold communicate with the orifices of the respective pyramids. The advantages claimed for the Wheeler filter bottom are the better distribution of wash water secured by uniform material uniformly placed; the absence of metal in contact with the water, thereby increasing the life of the bottom; and its lower cost.

Probably the newest and yet the oldest type of filter bottom is that exemplified at Alliance, Ohio; Muncie, Ind.; Warren, Pa.; Shreveport, La., and Erie, Pa. This consists of a false metal bottom into which brass strainer nozzles are screwed, spaced

6 in. apart. It is the false bottom of the earlier design, but the strainers with fine openings have been replaced with those having large openings. The gravel layer has been deepened, and wash water of high velocity is used. False bottoms of concrete have been suggested and have been built at Miraflores, C. Z., and at East Liverpool, Ohio; but the difficulties in the way of the successful design of a tight structure of this kind have caused conservative engineers to avoid it. Furthermore, it is believed that the space beneath the false bottom is a disadvantage, as mentioned above.

Mr. William Wheeler is now building for the Winchester Water Works Company (Ky.) a filter bottom having the usual pyramids and balls, but instead of channels beneath the pyramids there is a rectangular space like the filters mentioned above.

The most generally satisfactory strainer systems are the following:

1. Manifolds, strainers and a 14-in. layer of gravel.
2. The Harrisburg system of perforated pipes with a 14-in. layer of gravel.
3. Troughs having strainers at their bottoms, with a 14-in. layer of gravel.
4. The Wheeler filter bottom with 8 in. of gravel.

All of these systems should be designed to wash the sand layer without the use of air. Each system has its advantages and disadvantages, but the excessive cost of system No. 3 makes its use inadvisable. There are, therefore, three systems left. Of these, system No. 2 — the Harrisburg system — is the simplest. It, however, consists largely of metal, all of which is exposed, and at the present prices is probably more expensive than the Wheeler filter bottom. System No. 1, like that installed by most of the filter companies, possessed the advantage over system No. 2, the Harrisburg system, of having the outsides of the pipes protected by conerete. The strainers, however, are exposed and must be constructed of bronze, which at present prices makes the installation costly, probably the highest of the three. The insides of the pipes are likewise exposed.

In either of the above systems there exist "dead" spaces on the floor of the filter between the openings, where the wash water

does not readily reach. This difficulty is overcome in systems Nos. 3 and 4, of which No. 4, the Wheeler filter bottom, is the cheaper. The advantages of the Wheeler filter bottom consist in the absence of metal (with the exception of the short brass tube at the apex of the pyramid); the nearly perfect distribution of the wash water secured by the " ball nozzle " effect of the balls; the lower cost, and the thinner gravel layer. The writer of these notes believes that the Wheeler filter bottom is best when placed above channels rather than built as a false bottom of the filter, although to construct the latter is perfectly feasible.

Considerable difficulty has been experienced with the Wheeler filter bottom at Akron because of sand passing through the gravel around the walls of the filter, particularly at the corners. The writer has investigated this filter, and found that there was a ledge 1 in. wide left around the walls of the filter, and furthermore, the gravel layer was only 6 in. in depth. It was very difficult for the workmen to spread 1.5 in. layers of gravel evenly in the large units (2 000 000 gal. daily); consequently the sand had passed through the gravel in certain places until it rested on the ledge around the walls of the filter. This sand remained inactive. The difficulty was overcome by increasing the thickness of the gravel layer around the walls of the filter, particularly at the corners. Less than 0.5 per cent. of the area of the filter was involved. This is a very low percentage of sand surface out of action because of lumps, hard spots, etc., and the difficulty can be readily overcome. It would probably be best in a new filter with this bottom to make the gravel layer 8 in. in thickness, — namely, 4 in. coarse gravel, 2 in. medium gravel, and 2 in. fine gravel, rather than 3 in., 1½ in. and 1½ in., respectively, first used. Where the filter area is small, the thicknesses of the gravel layers may be reduced to those last given.

In large filters there seems to be a tendency towards wave motion in the underdrains, which may accumulate pressure at certain points in the filter bed, particularly at the ends of the channels, and may possibly cause the rupture of the gravel layer if it be too thin. This statement of course applies equally well to the three systems under consideration. The Wheeler filter bottom is better designed to resist jet action from the strainers

than are either of the others. The effect of a large ball immediately above the orifice is absolute and unchangeable.

The discussion regarding choice of filter bottoms at present centers around the relative merits of the false bottom and the strainer or manifold type. The false bottom was used in the Miraflores (C. Z.), Erie, and other plants, but only a few plants have been so built. The fear in the minds of operators of filter plants is that they may not prove so efficient bacteriologically as a plant designed on the other plan. On the other hand, the false bottom approaches nearer the condition for successful washing, — namely, that of a series of orifices discharging from a tank, — but with underdrain channels of sufficient size, relative to the areas of the orifices discharging from them, good enough distribution may be secured for all practical purposes, and the dangers, both structural and in operation, which the false bottom presents, avoided. There should be no objection to the use of the false bottom in small filters.

Thirty years' experience, and the results of experiments by Ellms and others, indicate that the successful filter will be washed at a high velocity with water alone. This effect is best secured by a strainer system consisting of orifices, above each of which is placed a layer of graded material to prevent sand from passing out of the filter, either when filtering or washing.

The underdrain system should be designed to throttle the discharge of wash water to the orifices. The latter should be reasonably large to avoid unusual loss of head in the filter, and the underdrains should be proportioned to the orifices. The false bottom system, while cheaper, is not so reliable as the other systems, and there are more or less troublesome results from cast or wrought iron headers and manifold strainer systems, even when they are cheaper, which is rarely the case. The Wheeler bottom, with sufficient gravel, best fulfills the conditions of practice. It is, however, on account of its being a patented device, more expensive than the Harrisburg system. On the other hand, it is more durable.

Discussion.

Mr. Harold C. Stevens. Mr. Weston spoke of the necessity of avoiding considerable resistance at the entrance to the strainers, the purpose being to minimize the effect of lost head as the water passes from the entrance to the strainer system into the strainer. I suppose at the older plants there may be a loss of head of a foot, which might correspond to the difference in discharging capacity from the near strainer to the far strainer of as much as ten per cent. That would tend to permit clogging to take place first along the sides or the corners of the tanks and work gradually towards the centers. Very likely there are a great many plants where the sand bed has to be taken out and cleaned with comparative frequency, which could be improved by putting in new strainers with greater resistance and by modifying old ones to give the same resistance.

REPORT OF THE JOINT COMMITTEE ON WATER CONSUMPTION.

[*Presented September 13, 1917.*]

This committee was appointed for the purpose of securing, by coöperation with the American Water Works Association, a standard form for water consumption statistics that would be adopted by both associations. The American Water Works Association appointed the following conference committee: Edw. S. Cole, chairman; Wm. W. Brush, J. N. Chester, J. H. Dunlap, J. H. Purdy.

Joint meetings have been held, and various members of the committee have presented their views in writing. A joint report was prepared with the unanimous assent of both committees, which was presented to the American Water Works Association at its annual convention in Richmond, in May, 1917, and formally adopted.

Your committee submits, for consideration, two forms to be used in the collection and publication of water consumption statistics. These forms are described as follows:

Form " A," to be used when only water consumption statistics and those closely allied thereto are to be presented.

Form " B," to be used when incorporated in a report, based on the form adopted by the New England Water Works Association and by the American Water Works Association in 1908.

These forms are attached hereto. They have been made as simple as possible, and consistent with the presentation of information which it is believed will be useful to the water supply profession.

Your committee has been impressed by the dearth of water consumption statistics which are comparable and typical of the various sections of this country. It believes that this Association would be rendering a service that the membership generally would appreciate, if the Association should publish yearly the consump-

tion statistics of typical communities in the various sections of our country. These should be selected so that the statistics of a fully metered community would be placed in comparison with those of a city in which only a small fraction of the supply is metered. By selecting, say, from fifty to one hundred of such communities and enlisting their aid in furnishing accurate statistics, information of great and increasing importance would be made available. Each five years, beginning with the year 1920, statistics should be published, setting forth the more important water consumption figures for a much larger number of cities, selecting these so that a reasonable percentage of each size would be recorded. It is suggested that this list include all cities having a population of over 500 000, 50 per cent. of those having a population of from 250 000 to 500 000, 25 per cent. of those having a population of from 100 000 to 250 000, and 10 per cent. between each of the following limits:

50 000 to 100 000.
25 000 to 50 000.
10 000 to 25 000.
Under 10 000.

By coöperation with the American Water Works Association, the labor and expense of collecting and publishing this information can be divided between the two associations, and the information furnished to the combined membership.

Your committee makes the following recommendations:

First: That Form "A" be adopted for use where water consumption statistics only are to be recorded.

Second: That a committee on uniform annual reports be appointed, the membership to represent those interested in pumping, filtration, water consumption, distribution, services, meters, and financial questions; that the American Water Works Association be requested to appoint a similar committee; that these committees, if possible, agree on a statistical form which will cover the entire water-works field; that the committee of this Association report at the next annual meeting the form recommended; and that this committee also report to what extent the Association should collect and report statistics, giving the names of the com-

munities from which such statistics should be regularly obtained and published.

Third: That your present committee should be finally discharged.

Respectfully submitted,

EDW. S. COLE, *Chairman.*
C. M. SAVILLE.
D. A. HEFFERNAN.
P. R. SANDERS.
E. W. KENT.

NEW YORK CITY, N. Y.
August 1, 1917.

FORM "A."

(To be used when only water consumption statistics and those closely allied thereto are to be presented.)

1. City or town.....
2. Year for which report is made.....
3. Municipal or private.....
4. Miles of mains.....
5. Range of domestic pressure.....Is fire pressure raised.....
   What is fire pressure.....
6. Population:
   (*a*) Total..... | Last United States census.....
   | Estimated total population this date.....
   (*b*) Supplied..... | Estimated total population supplied, using 5 per family.....
7. Total number of services in use.....
8. Total number of metered services.....
9. Per cent. of metered services (8 divided by 7).....
10. How is the total water consumption determined:
    (*a*) By meter upon supply main. (Yes or No).....
    (*b*) By plunger displacement. (Yes or No).....Slip allowed.....
    (*c*) Other methods. Describe.....
11. Total annual water supplied for:
    (*a*) *Domestic uses* by metered services.....
    (*b*) *Commercial use* by metered services.....
    (*c*) *Industrial use* by metered services.....
    (*d*) *Public uses* by metered services.....
    (*e*) Total metered use.....Estimated public use unmetered....
    (*f*) TOTAL ACCOUNTED FOR.....
    (*g*) Total annual amount of water supplied, gallons daily.....
    (*h*) TOTAL UNACCOUNTED FOR.....Per cent. total supply.....

12. Minimum night rate (1 A.M. — 4 A.M.).....
    State how this rate is obtained.....
13. Maximum rate
    (*a*) Without fire.....
    (*b*) With fire per hour.....per day.....per month.....
14. Total metered use per capita daily.....What population.....
15. Average supply per service per day, gallons.....
16. Average supply per day per capita based on:
    Total population.....
    Population supplied.....
17. Estimated total daily supply obtained by manufacturing or other plants from sources other than the city supply.....
18. Total per capita daily use, including all supplies.....
19. Cost of supplying water per million gallons, figured on total operating and maintenance.....
20. Total cost of supplying water per million gallons, figured upon total operating and maintenance, depreciation, and interest upon the fair value of the plant.....
21. Revenue per million gallons.....

NOTE. *Commercial:* Stores, office buildings, hotels, boarding houses, and similar establishments.

Industrial: Railroads, factories, public gas and electric plants.

Public: All water for public use.

FORM "B."

(To be used when incorporated in a report, based on the form adopted by the New England Water Works Association in 1902.)

1. How is the total water consumption determined:
   (*a*) By meter upon supply main. (Yes or No).....
   (*b*) By plunger displacement (Yes or No).....Slip allowed.....
   (*c*) By other methods. Describe.....
2. Total annual water supplied for:
   (*a*) *Domestic uses* by metered services.....
   (*b*) *Commercial use* by metered services.....
   (*c*) *Industrial uses* by metered services.....
   (*d*) *Public uses* by metered services.....
   (*e*) Total metered use.....Estimated public use unmetered.....
   (*f*) TOTAL ACCOUNTED FOR.....
   (*g*) Total annual amount of water supplied, gallons daily.....
   (*h*) TOTAL UNACCOUNTED FOR.....Per cent. total supply.....
3. Minimum night rate (1 A.M. — 4 A.M.).....
   State how this rate is obtained.....

4. Maximum rate:
   (*a*) Without fire.....
   (*b*) With fire per hour.....per day.....per month.....
5. Total metered use per capita daily.....On what population.....
6. Average supply per service per day, gallons.....
7. Average supply per service per capita, based on:
   Total population.....
   Population supplied.....
8. Estimated total daily supply obtained by manufacturing or other plants from sources other than city supply.....
9. Total per capita daily use, including all supplies.....

NOTE. *Commercial:* Stores, office buildings, hotels, boarding houses, and similar establishments.

Industrial: Railroads, factories, public gas and electric plants.

Public: All water for public use.

SOME EXPERIENCES WITH A TRENCHING MACHINE.

BY GEORGE W. BATCHELDER, WATER COMMISSIONER,
WORCESTER, MASS.

[*Read September 12, 1917.*]

In 1913 it became evident that the city of Worcester had outgrown its water supply lines, and plans were accordingly made to lay additional pipes in 1914.

In preparing for the large work which was to come, the question of the most economical methods suggested the advisability of using a trenching machine. After examining several different machines, it was decided to purchase an Austin machine, which was secured at a cost of $7 000 less 5 per cent.

This machine reached the city in due season, was unloaded and driven to the scene of its first work by a demonstrator sent by the company at the expense of the city. The machine was put to digging a trench on Stafford Street for a 36-in. pipe buried in a trench approximately 6 ft. deep. It was equipped for this work with buckets 36 in. wide, the teeth on which projected 3 in. on each side, making a cut 42 in. wide.

As it was necessary to make the trench about 5 ft. wide, this was accomplished by barring down the banks of the trench in advance of the buckets, and feeding material so broken off into the machine as it operated. From two to three men were used on each side of the ditch to handle the bars and break down the banks. The capacity of the machine is so great that it will take out all the material dug in the regular way in addition to that tumbled into the ditch by the use of bars.

In digging this ditch on Stafford Street varying kinds of material were encountered; at the beginning, the soil was quite a heavy gravel containing some bowlders of considerable size; later, a fill was reached, and from the bottom of the trench the machine removed without difficulty a considerable number of flagstones approximately 3 ft. long by 18 in. in width.

Later a fine gravel, and still later a heavy gravel, was encountered, which the machine handled without difficulty.

In another part of the location the soil was largely composed of sand through which the machine plowed its way with great ease and speed; so rapidly, in fact, that it was operated for only a few hours each day, it being found that the pipe-laying organization could not keep pace with it, and it was impracticable to open too long a trench.

Thirteen thousand feet of this 36-in. pipe was laid in 1914, and the machine did the rough trenching for about 9 000 ft. The machine was then driven to Chandler Street, and put in service excavating for a 48-in. and 42-in. pipe. The extra width of trenching was handled in the same way as previously explained, and with equal satisfaction.

Later a cut of several hundred feet of trench for a sewer 12 ft. deep was made in extremely hard clay, reducing the cost of the work very materially over hand labor.

The machine can be used to the best advantage in new streets, but it can be operated without extreme difficulty in city streets by raising the boom at points where cross connections are encountered and lowering again after they are passed. It cannot be used conveniently in narrow streets except by closing them to traffic.

The best way to operate the machine is to rig it to convey the spoil to a bank on the extreme side of the street, with the pipe on the opposite side ready to be rolled over to the trench when the machine has passed.

While the city of Worcester lays many miles of water pipes each year, the problem has been to find work for the machine, and it has been rented at various times to the mutual advantage of the city and the contractors.

The machine is so well known to the members of this Association that a description of it would be superfluous, especially as it is now in service in Hartford, and an opportunity to see it in action will be available.

It has given excellent satisfaction, and in such times as these, when scarcity of labor prevails, it makes the work of pipe laying possible with a small number of men. It is seldom out

of repair, standing up under the rugged work it has to do in an excellent manner. The necessary repairs consist principally of replacing occasional broken teeth on the buckets or links for the chain.

Its capacity has not been fully determined in Worcester, because the pipe-laying organization was never large enough to keep within sight of it. It has made, under good conditions, a cut 6 ft. deep and 5 ft. wide at a rate of 18 in. a minute, or 20 ft. an hour, and has been estimated to cut a trench as rapidly as 150 men would do it.

Records show that it will deposit on the bank ordinary gravel or sand at a cost of approximately five cents per cubic yard.

The machine requires from ninety to one hundred pounds of coal per hour, two quarts of cylinder oil, one pint of machinery oil, and about two pounds of cup grease per day.

It requires two men, one operator and one fireman. There should be at least one man in the rear of the machine to look after conditions in the trench, to warn the operator of the presence of large bowlders or anything else which might interfere with the safe operation of the machine, to signal to stop before large stones are dropped on the conveyor belt, and in general to assist the operator.

More men are of course needed if the trench is to be wider than the regular width of the cutters, and to help in removing large stones after they are brought to the surface by the buckets. Records picked at random show what the machine has done on many occasions in this city; the time given in each case is the total time, which includes starting, stopping, and idle periods when hand work is being done in the trench.

June 26, 1917, New Park Avenue, 155 ft. long, 36 in. wide, 5 ft. deep, 5 hours
June 27, 1917, New Park Avenue, 200 ft. long, 36 in. wide, 5 ft. deep, 6 hours
July 6, 1917, New Park Avenue, 220 ft. long, 36 in. wide, 5 ft. deep, 7 hours
July 19, 1917, New Park Avenue, 320 ft. long, 36 in. wide, 5 ft. deep, 8 hours
July 24, 1917, Quaker Lane, 408 ft. long, 24 in. wide, 5 ft. deep, 8 hours

A valuable machine to use in connection with the trenching machine is the back-filling machine made by the same concern which builds the trenchers. It consists of a portable gasoline

engine running by its own power and handling a scoop bucket on the end of a boom which projects from the machine across the ditch to the spoil bank.

The method followed in Worcester has been to securely bed the bottom of the pipe by hand filling and tamping; then the great bulk of the material was scooped into the trench by the machine and puddled or tamped as the work progressed.

To persons who have seen the leisurely manner in which many men back fill trenches, it is refreshing to see this back filler eat into a bank and scoop the earth back into the trench. Three men are enough to operate the back filler, — one man who rides and operates the machine and two men on the handles of the scoop.

It has been found practicable to use the trenching machine operator on the back filler, as otherwise the trencher would get too far ahead of the rest of the organization.

The purchase and use of these machines has saved the city of Worcester large sums of money and made possible the laying of long lines of pipe without prohibitive costs.

A growing city needs such machines as these, to do its work in an economical and prompt manner. With the present scarcity of labor, which is likely to continue, the necessity of labor-saving machinery such as above described is evident.

EXPERIENCES WITH UNIVERSAL CAST-IRON PIPE.

BY JOHN H. WALSH.*

[*Read September 12, 1917.*]

The Borough of the East Hartford Fire District began using the Universal pipe in 1908. We laid an 1 800-ft. line of 4-in. pipe in June, 1908, and since that time we have laid approximately 45 000 ft. of Universal pipe, sizes 4 in., 6 in., and 8 in. The first line laid has been in use now for nine years, and our records will show that we have not spent one cent on this line for repairs that were necessitated by any deficiencies in the pipe itself.

In January, 1909, the new line froze near the end, and four water-takers were cut off from water supply. We found it would be very expensive to try to thaw out the frozen part of the line, and the water-takers had wells that could be used in an emergency. So we did nothing to it until the latter part of February, when a warm spell came and relieved the frost in the ground — then the trouble began.

I was called on a Sunday morning to fix a bad leak on the line. With three men I started out in a team, taking two lengths of 4-in. Universal pipe. We drove five miles to the leak, and found that one length of pipe was cracked in the middle for a length of 18 in. We shut off the line and uncovered three lengths of pipe, or 18 ft. (the pipe is in 6-ft. lengths), and in one hour we had the water turned on again. In renewing the burst pipe we took the bolts out of two joints and loosened the bolts in the other two joints, and raised the pipe until the ends came apart. We then laid in the new pipe, dropped the joints down, tightened the bolts, and covered up the pipe. This was my first experience with Universal pipe. From that time on I have always said that this is the only pipe. It is easy to lay, easy to repair, and never gives you any trouble if properly laid and the frost doesn't catch you.

After a few hours of instruction, an ordinary laborer can lay this pipe. To lay the 4-in. pipe we need four men, — two men

* Superintendent of Water Works, East Hartford, Conn.

to get the pipe ready, and two men in the trench to lay and bolt it together. On the 6-in. and 8-in. pipe we need six men. On several extensions of the 4-in. lines we have laid 100 lengths of pipe, making 600 ft., with four men. This was accomplished in eight hours.

Several improvements have been made in the pipe during the nine years that we have been using it, such as bracing the lugs and strengthening the bell end. It can be bought in lengths from 12 in. up to 6 ft.; all kinds of bends, tees, crosses, and drop offsets, that are used in the laying of water mains, can be had for the asking. I believe our water department was the first one to call for the drop offsets, which we use in going over or under an obstacle when new lines are being laid or changes made in highways, when one must come up or go down.

Another good point I find about Universal pipe is that electrolysis will not affect it. I had trouble from burn-outs by electricity on a line we had of 4-in. bell and spigot pipe that went under a web of trolley switches and tracks. We removed the bell and spigot pipe for a distance of about 100 ft. and laid in Universal pipe. That was five years ago, and we have never had to make any repairs there since.

In our outlying farming districts, where we lay pipe to serve the farmers, we use the country roads and sometimes have to make some very short curves. I find that the Universal pipe is well adapted for this purpose. I always use, in rounding curves, a short length, say 2 ft. long, then a 6-ft. length, and 3-ft. lengths, and so on until the desired bend is accomplished. Before testing the pipe on curves, we brace the pipe against the side of the ditch with flat stones about 6 ft. apart. These braces we leave in permanently. The reason for bracing the pipe in this manner on curves is for safety when testing the pipe. Wherever we lay pipe, whether on short or long curves, we usually turn in the water and get the regular pressure on the pipe line; the gate is then shut off and we make a connection on the end of the line at the blow-off plug. We attach a pump and send the pressure up to one or two hundred pounds, and keep it there until every joint is thoroughly inspected. The pressure is then gradually let off, and everything is ready for the back filling.

In our soil, which is mostly sand, we do considerable tunneling if we are laying pipe in and along macadam roads. We dig up 8 ft. and leave 4 ft., and by measuring with a 6-ft. pole one can get the joints in the open ditch; in this way the 3-in. and 4-in. and 6-in. pipe can easily be laid. In crossing improved concrete or any kind of hard roads up to 25 ft. in width, we always tunnel the pipe through. We open the trench at each side of the roadway long enough to take in the 6-ft. lengths of pipe required to go across the road. The pipe is bolted up tightly together and both ends plugged and filled with water. We attach our pump and get the required pressure to test the joints. The water is then let out, a rope is passed under the street through the tunnel, a block and falls are used, and the pipe pulled through and bolted to the end of the pipe coming from the main line.

In conclusion, I wish to say that there are lots of little tricks that will save time and money that can be done with the Universal pipe that cannot be done with the bell and spigot pipe. At least, I have found it so in my experience with the Universal pipe joint. You need no lead, no calking — just ordinary laborers to do the work; and a little can of clean grease, a ratchet wrench to tighten up two bolts, and you have a water pipe joint that cannot be equaled in cast-iron pipe joints.

Discussion.

Mr. S. H. McKenzie. We have used a very little of that pipe, the first being laid in 1911. At the present time we have something like 25 000 ft., and it certainly has been good pipe. The first pipe that we laid was the line of 100-lb. pipe, and it has been in under a pressure of over 100 lb. since 1911, and we haven't spent one cent on it. When we thought of putting in Universal pipe our commissioners were a little bit skeptical in regard to it, so that for a test I put a gage on that line, something like 1 100 ft. long, and the gage held absolutely to the pressure at which the water was turned on. And we have laid perhaps 2 000 ft. and had the gage hold pressure over night.

About two years ago we laid a line of about 9 000 ft., of which 6 000 was in water. If we had used ordinary pipe on that special

extension the cost would have been prohibitory. There was a large quantity of water running. We sawed some pieces of $\frac{7}{8}$ board about 8 or 10 in. long, and put one of those in the ditch once in 10 ft., and laid our pipe on that, and then used a pump at the lower end of the ditch where we commenced to lay, which took care of all the water, and we were able to lay a whole day's work with just that one pump going, and if there had been bell-holes we would have had to have a man at every bell-hole. On one other extension we put in something like 9 000 ft., a good quantity of which was also in water, and more in sand cuts; and, taking both of those jobs which are naturally bad, we laid hundreds of feet at a figure as low as 66 cents a foot, including the cost of the pipe. That was about three years ago.

In regard to the joints, we have found that if we use an elastic paint in the joint it works out very well. I think it is better than the white lead, as it absolutely fills up any little depressions that might appear in the joints, and it also coats over the machined part of the joint, which is not covered when the pipe is pulled in, and where the pipe might be apt to rust up. When the pipes are taken apart, that coating is found intact. Sometimes the ends of the pipe are not coated. That is, the male end. And if you have that painted with this elastic paint it does away with the danger of the cast iron rusting up. I don't know that we have ever had in the thousands of feet that we have laid any split bells except once, and that was in a piece of 4-in. pipe. We laid 400 or 500 ft. to a drop-forge shop, a couple of years ago, of 8-in. pipe, and up to the present time that seems to have held tight. I didn't know but the heavy drops might have a tendency to shake the joints so that they might leak. But the only trouble that we have had in that line, so far, was in one joint, and that was very easily repaired.

One thing that is important in using the Universal pipe is inspecting the pipe carefully before it goes into the ditch. See that the burr on the male end is all right before you put your pipe together, for if you don't, and it is not filed off, it will make a groove in the female end, and consequently there will be a leakage in the joint. But if you turn the water on at night and turn it off in the morning, about nine times in ten you will find the joint dry.

MR. F. L. FULLER. I should like to ask if there is any danger of these bolts rusting out.

MR. MCKENZIE. The bolts are very heavy, — $\frac{5}{8}$- and $\frac{3}{4}$-in. bolts, — and, if you have ever noticed, in taking the bolts apart, for instance, on your gates, the thread inside of the nut is as a rule intact, and it would take a long time to rust a $\frac{3}{4}$-in. bolt through.

MR. ——— ———. Can some gentleman present answer the question whether the pipe is cast vertically or horizontally? It is quite an interesting point with me because I have had some experience with it, and the excuse that was made at the time was that the pipe was cast horizontally. I have some pipe in connection with our system that has never yet been able to stand the pressures.

MR. ALFRED D. FLINN. I am informed the pipe is cast horizontally.

MR. ——— ———. The case I referred to, we had a pressure of 125 lb. The pipe was supposed to stand that pressure. It has never yet been able to stand up to 100. Consequently, the main is lying idle, never has been put in service.

THE RESULTS OF THE USE OF METERS IN THE METROPOLITAN WATER DISTRICT, BOSTON.

BY SAMUEL E. KILLAM, SUPERINTENDENT PIPE LINES AND RESERVOIRS, METROPOLITAN WATER WORKS, BOSTON, MASS.

[*Read September 13, 1917.*]

It is a matter of history that the city of Boston first introduced service meters as early as 1852, as a means of checking waste. At this early date, four years after municipal water had first been introduced, waste of water became a source of anxiety to the Cochituate Water Board, and the following is taken from a report of that year: "The quantity that is used and wasted is more than double what was anticipated to be sufficient for our present population." The consumption was 8 125 800 gal., equivalent to 55 gal. per capita.

The first meters installed were known as the Huse meter, but they were not very reliable, and during the next ten years the work of installing service meters was mainly experimental. In 1861 there were 104 service meters in use, most of which had been applied to the leading hotels. The use of meters was extended year by year until in 1871 there were 1 091 meters in service. Then came a change in policy, and during the next nineteen years only six meters were installed, but in the meantime the new Sudbury River works had been completed, which promised an "inexhaustible" supply.

The quantity of water delivered to the distribution system continued to increase, and in 1879 the consumption on the high-service district, which was almost entirely for domestic use, was at the rate of 110 gal. per capita per day during the day hours and 72 gal. per capita per day during the night hours, from 11.00 P.M. until 4.00 A.M.

In the Charlestown district of Boston, in 1881, an experiment was made by using the Deacon meters to detect waste, and the per capita consumption was reduced from 58.5 gal. per day to

37.7, but the subject of waste was not taken up in earnest until July, 1883, when a systematic plan of inspection and of observation by operating the waste detector meters by districts was inaugurated under the personal supervision of the late Dexter Brackett.

In addition to the Deacon waste observations, a house-to-house inspection was made, which resulted in the issuance during the first four months of over 6 000 notices to stop the waste of water from house fixtures. The consumption in some districts at this time was reduced over 35 per cent. Much waste of water was prevented by the inspection of house plumbing, and, aided by the use of Deacon meters, the consumption was reduced from 91.5 gal. in 1883 to 68 gal. per capita in 1884.

The inspection was continued with decreasing diligence for about ten years, but the checking of waste was not permanent, and the consumption of water continued to increase as in former years.

In the early nineties it became apparent that the city of Boston had nearly reached the capacity of its sources of water supply, and there were several nearby cities and towns whose sources of supply were being investigated as to quantity and quality.

By an act of the General Court approved June 9, 1893, the State Board of Health was directed to investigate the subject of a future supply for the Boston Metropolitan District, and in February, 1895, a report was made recommending the taking of the waters of the south branch of the Nashua River at a point in the town of Clinton, the works so constructed to be utilized in conjunction with the sources then in use by the city of Boston.

The Metropolitan Water Act was approved June 5, 1895, which provided for a board of three commissioners to construct, operate, and maintain a system of water works substantially as recommended by the State Board of Health. The act further provided that a city or town, any part of which was within a radius of ten miles of the State House, should, upon payment of such sums as should be determined by the board, be admitted into the district. Subsequent legislation combined the Metropolitan Water Board and the Metropolitan Sewerage Commission into one commission known as the Metropolitan Water and

Sewerage Board, consisting of three members appointed by the governor. The board at present is made up as follows: Henry P. Walcott, M.D., chairman; Edward A. McLaughlin, and Thomas E. Dwyer; with William E. Foss as chief engineer of water works.

The Metropolitan Water District at present is made up of the following cities and towns: Arlington, Belmont, Boston, Chelsea, Everett, Lexington, Malden, Medford, Melrose, Milton, Nahant, Newton, Quincy, Revere, Somerville, Stoneham, Swampscott, Watertown, and Winthrop. The town of Swampscott was admitted under a special act of the legislature, it being outside of the ten-mile limit prescribed in the act. The city of Newton, which is a part of the district, is still supplied from its own local source.

On January 1, 1898, the works were so far completed that formal possession was taken of the collecting works of the city of Boston, and actual operation and maintenance commenced.

Previous to the formation of the Metropolitan Water District, nearly all the cities and towns obtained their supplies from local and different sources and maintained separate pumping units, storage reservoirs, and distribution systems. After the Metropolitan Works were put in service, eleven sources of supply were abandoned and five pumping plants operated in place of twenty.

The water is delivered to the district from the Wachusett, Sudbury, and Cochituate watersheds by gravity through aqueducts, and the low-service districts are supplied in most part without pumping. In 1916, about 45 per cent. of the entire supply was delivered by gravity directly to the distribution system, the remainder being pumped and 1.4 per cent. being raised a second time by pumping for the higher elevations in the district.

In 1902, under act of the General Court, Chapter 391 authorized the Metropolitan Water and Sewerage Board to construct works for the measurement of water supplied to the cities and towns in the Metropolitan Water District and to report the quantity supplied to each, and also whether the water was being improperly or unnecessarily used, and to make recommendations in regard to preventing waste and the manner of proportioning the annual water assessment.

Before measurements to determine the quantity and waste could be made, it was necessary to provide means for measuring the water supplied to the cities and towns.

In anticipation of the passage of the act, extended studies had been made to determine the number and size of the meters which would be required for measuring the water. The Venturi meter was adopted as the best and most suitable device to measure the large quantities required without too great a loss of head. This meter is a specially designed pipe which contains a contracted section called a throat, which causes a depression in the hydraulic gradient. At the inlet end and at the throat small holes are drilled into the tube, and service pipes which transmit the pressures are connected with the registering instrument, which may be located some distance from the tube. Since the meter tube contains no moving parts or obstructions, the wear on the interior surface is imperceptible, and a throat which was recently removed after seventeen years' continuous service was found to be in excellent condition.

There are now sixty-nine meter tubes installed in the district, varying in size from 6 in. to 60 in.

The record of flow is obtained at the register, and is due to the difference of pressure on the level of a column of mercury, which carries a float. The position of this float is thus made dependent upon the quantity of water passing through the meter, and by suitable mechanism the quantity is recorded by counter and the rate of flow recorded on charts. The pressure at the throat of the meter is often several pounds less than at the inlet end, but the loss of pressure is nearly all regained at the outlet end of the tube.

There are several types of registers. All have been found to be simple and rugged in construction and responsive to minute variations in rates of flow. There are in use in the district fifty-four Type D, five Type M, and one Type V registers.

The autographic records from the registers give information regarding unusual drafts of water, and assistance has been given local water departments by notifying them of an increase of flow caused by underground leaks.

In districts where the quantity to be measured is small, the Hersey Detector meter, Model F. M., has been used.

The total cost to January 1, 1917, of installing the meters, including meter registers and appurtenances, was $94 364. The total cost for charts and repairs to meter registers since their installation in 1903 averaged about $3.50 per meter register per year.

Two men are required to devote their entire time to the reading and adjustment of the meter registers, and keeping the registers and steel tanks in which they are located in good condition. The meters are read twice each week, requiring the equivalent of eight days for one man.

A report* on the measurement, consumption, and waste of water supplied to the Metropolitan Water District, with recommendations, was made by the Metropolitan Water and Sewerage Board to the General Court in February, 1904, which resulted in the passage of an act providing that the water assessment for each municipality supplied by the Metropolitan Works be based on the valuation and consumption after the year 1905, in the ratio of one-third valuation to two-thirds consumption of water. Following as it did the investigation of the leakage in the district, made by the Metropolitan Water and Sewerage Board in the years 1903 and 1904, it is fair to assume that the act levying a part of the water assessment on consumption was a factor in keeping down the per capita consumption during the next few years.

In 1907 an act was passed providing that after January 1, 1908, all cities and towns which derived their source of supply from the Metropolitan Water Works should equip all new service pipes with water meters, and should also equip annually with meters 5 per cent. of the services that were unmetered on December 31, 1907, and should thereafter charge each consumer in proportion to the amount of water used.

The quantity of water consumed became a very important element, and it was made an incentive, not only for the district as a whole, but for each municipality, and finally, the most important of all, each consumer, to check and to stop the unnecessary and wasteful consumption of water.

The gradual installation of more service meters in the district has reduced the average daily consumption per inhabitant from 130 gal. in 1907 to 89 gal. in 1916.

* Reprinted in JOURNAL N. E. W. W. A., Vol. 18, page 107.

The area, population, number of service pipes, meters, and miles of pipe in use in each city and town in the district, are given in the following table:

City or Town.	Area, Square Miles.	Estimated Population, July 1, 1916.	Services in Use, January 1, 1916.	Meters in Use, January 1, 1916.	Miles of Pipes, January 1, 1916.
Arlington	5.2	15 670	2 753	2 755	45.10
Belmont	4.6	8 560	1 430	1 430	29.38
Boston	42.8	762 700	103 195	54 848	849.35
Chelsea	2.3	45 020	4 971	4 957	43.30
Everett	3.4	38 870	5 893	2 947	50.21
Lexington	16.0	5 680	1 156	1 063	36.32
Malden	4.9	50 160	8 055	7 696	90.18
Medford	7.1	32 080	6 043	5 846	67.19
Melrose	5.1	17 260	4 005	4 211	52.99
Milton	12.9	8 850	1 867	1 926	50.06
Nahant	1.0	1 440	730	468	22.07
Quincy	16.5	42 030	9 315	8 248	129.74
Revere	5.9	26 790	4 413	3 125	52.99
Somerville	4.2	89 190	13 233	9 155	95.42
Stoneham	6.6	7 590	1 613	1 589	26.13
Swampscott	3.1	7 580	1 810	1 810	21.99
Watertown	4.1	17 280	2 798	2 622	38.20
Winthrop	1.6	13 470	2 903	2 829	32.23
District	147.3	1 190 220	176 183	117 525	1 732.85

The climatic and industrial conditions are immediate factors in considering the difference in the amount of water consumed in the various districts for different years. In Boston the quantity used for business and manufacturing is larger than in any other municipality. The traveling, or suburban, population from outside the city use the water but are not included in the census population upon which this per capita consumption is based. However, if Boston is divided into various districts, as measured by the master meters, it will be observed that there has been a decided decrease in the per capita consumption in the districts since the installation of service meters.

The per cent. of services metered and the per capita consumption per day and at night in each city and town in the district for the years 1907 and 1916 was as follows:

City or Town.	Per Cent. of Services Metered.		Consumption per Capita. Gallons per Day.			
			1 A.M. to 4 A.M.		Average Daily.	
	January 1, 1907.	January 1, 1916.	1907.	1916.	1907.	1916.
Arlington	33.6	100.0	50	28	91	59
Belmont	100.0	100.0	31	18	68	52
Boston	5.5	53.2	107	62	153	105
Chelsea	14.6	99.7	59	35	97	68
Everett	2.0	50.0	50	42	82	74
Lexington	2.1	92.0	43	37	69	69
Malden	93.6	95.5	22	28	46	49
Medford	10.5	100.0	65	22	102	46
Melrose	3.9	100.0	85	26	117	45
Milton	100.0	100.0	16	10	46	42
Nahant	17.2	64.1	50	51	130	110
Quincy	14.2	88.6	66	39	100	59
Revere	4.8	70.8	54	34	82	59
Somerville	24.6	69.2	55	34	90	69
Stoneham	1.9	98.5	55	29	91	58
Swampscott	37.8	100.0	41	28	85	59
Watertown	98.3	100.0	36	29	67	65
Winthrop	2.3	100.0	65	26	105	53
District	14.7	66.8	88	51	130	89

The following table gives the per capita consumption in gallons for several years in the various districts into which the city of Boston is divided by master meters.

District by Services.	1907.	1908.	1909.	1910.	1913.	1916.
Southern Low	148	148	139	128	126	115
Southern High	162	158	151	128	100	105
Charlestown	200	195	186	188	114	113
East Boston	130	140	117	110	58	61
Brighton	132	135	108	107	77	89
West Roxbury	130	131	112	132	92	57
Breeds Island	63	60	61	53	35	31
Total	153	153	143	130	109	105
Per Cent. of Services Metered	5.6	5.7	5.8	12.5	34.8	53.2

The southern low-service district comprises the lower area of the city proper, South Boston, Dorchester, and Brighton, in which is located the greater part of the business and manufacturing plants, railroad terminals, and electric light and power plants. All the other districts are residential, although the southern

high-service district includes several of the largest hotels and some business and manufacturing plants. In East Boston and Charlestown, considerable quantities of water are used by railroads and shipping and some by manufacturing plants.

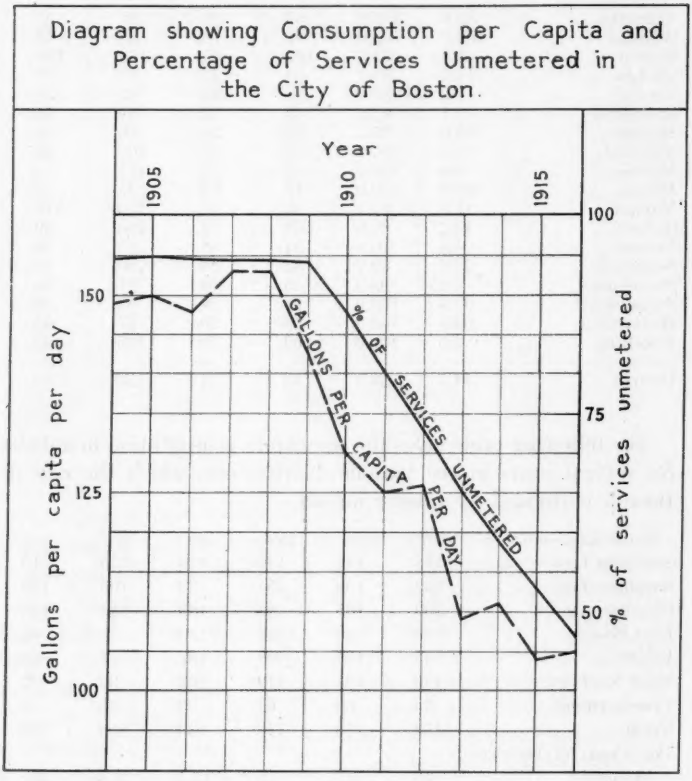


FIG. 1.

The effect of the use of service meters upon consumption of water is very graphically illustrated by the accompanying diagram, Fig. 1, showing the daily number of gallons used per capita in the city of Boston and the percentage of unmetered taps for each year, 1904 to 1916 inclusive.

There has been a gradual reduction in the quantity of water used with the increase in the use of meters.

In Melrose, which is largely residential, the reduction due to the installation of service meters was especially noticeable. The introduction of meters was begun in 1907, and on January 1, 1908, about 30 per cent. of the takers were changed from scheduled to meter rates, and at the end of the year 1908 practically all the services were metered. The records on the master meter showed a saving of 55 gal. per capita in two years, a reduction of 47 per cent.

The following table gives the per capita consumption in gallons by months, per cent. of services metered in the city of Melrose, and the average temperature of the air for the years 1907, 1909, and 1916.

	Daily Consumption per Capita.			Average Temperature of Air.		
	1907.	1909.	1916.	1907.	1909.	1916.
January	113	60	43	26.1	29.4	31.6
February	125	61	43	21.6	31.6	24.4
March	116	58	44	37.5	35.2	27.8
April	109	60	43	44.0	48.6	45.6
May	111	63	46	53.7	56.2	58.3
June	120	71	46	64.7	69.4	62.0
July	122	71	45	72.6	70.9	72.6
August	131	66	49	70.0	71.0	71.0
September	116	63	49	64.5	62.7	64.2
October	115	61	47	49.1	52.6	55.0
November	113	60	45	41.7	45.3	41.7
December	115	55	44	34.9	28.4	31.5
Year	117	62	45	48.4	50.1	48.8
Per Cent. of Services Metered	3.9	100	100			

The diagram, Fig. 2, shows graphically what has been accomplished in the district during the past eight years in reducing the waste of water, and at the same time indicates that while much has been accomplished, the work is still unfinished.

The fact that between the hours of 1 and 4 A.M., when the legitimate use of water is at its minimum, water is drawn from the mains in the district at the rate of over 60 900 000 gal. in twenty-

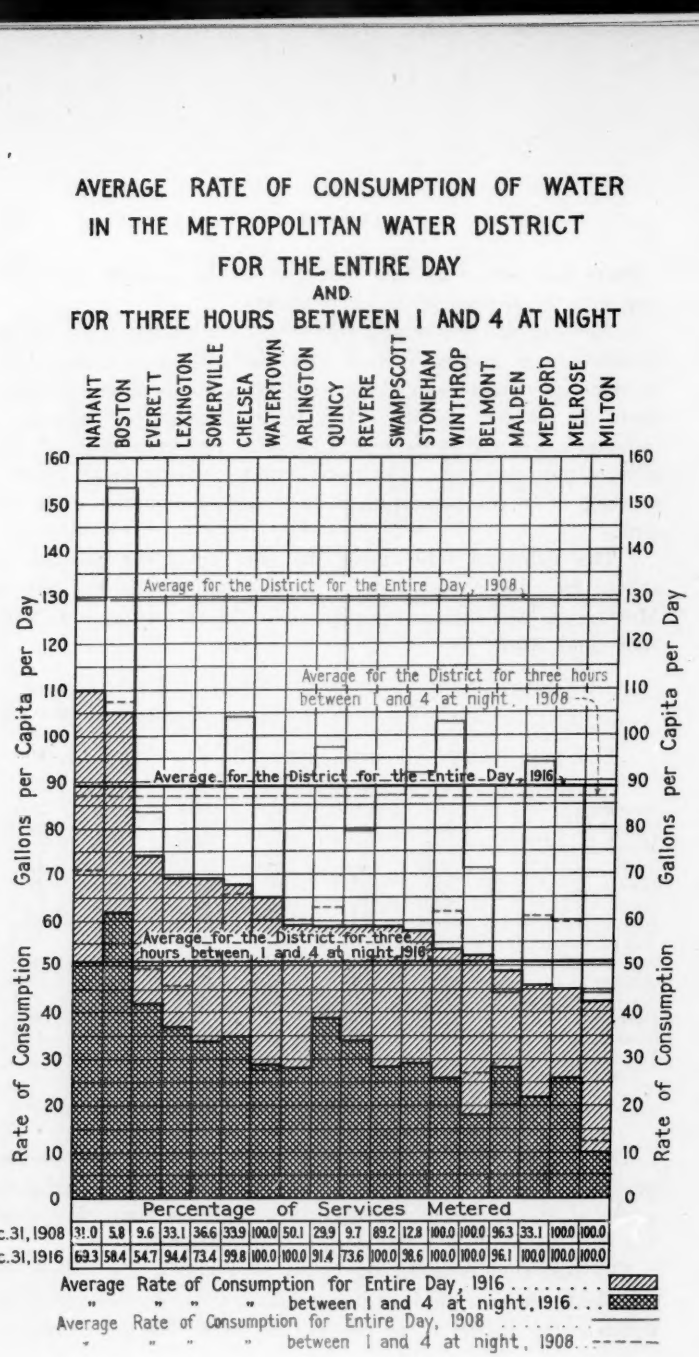

AVERAGE RATE OF CONSUMPTION OF WATER
IN THE METROPOLITAN WATER DISTRICT
FOR THE ENTIRE DAY
AND
FOR THREE HOURS BETWEEN 1 AND 4 AT NIGHT
NAHANT
BOSTON
EVERETT
LEXINGTON
SOMERVILLE
CHELSEA
WATERTOWN
ARLINGTON
QUINCY
REVERE
SWAMPSCOTT
STONEHAM
WINTHROP
BELMONT
MALDEN
MEDFORD
MELROSE
MILTON
Gallons per Capita per Day
Rate of Consumption
Average for the District for the Entire Day, 1908
Average for the District for three hours between 1 and 4 at night, 1908
Average for the District for the Entire Day, 1916
Average for the District for three hours between 1 and 4 at night 1916
Percentage of Services Metered
Dec. 31, 1908 31.0 5.8 9.6 33.1 36.6 33.9 100.0 50.1 29.9 9.7 89.2 12.8 100.0 100.0 96.3 33.1 100.0 100.0
Dec. 31, 1916 69.3 58.4 54.7 94.4 73.4 99.8 100.0 100.0 91.4 73.6 100.0 98.6 100.0 100.0 96.1 100.0 100.0 100.0
Average Rate of Consumption for Entire Day, 1916
" " " " between 1 and 4 at night, 1916
Average Rate of Consumption for Entire Day, 1908
" " " " between 1 and 4 at night, 1908

FIG. 2.

four hours, equivalent to 51 gal. per capita, is very strong proof that, notwithstanding the decrease in the consumption, a large amount of preventable waste is still taking place.

It will be noticed on Plate XI that notwithstanding the increase of over 335 000 in the number of people supplied, the average daily consumption was less in 1916 than it was in 1902, fourteen years ago, and the per capita consumption was the same in 1916 as in 1894.

The daily average quantity of water used in the district in 1916 was 17 808 000 gal. less than during the year 1907, and the per capita consumption has been reduced from 130 gal. to 89 gal., equivalent to over 31 per cent. This reduction in the use of water has been accomplished largely by the introduction of service meters.

The estimated safe capacity of the Cochituate, Sudbury, and Nashua supplies is 173 000 000 gal. per day. Assuming that there had been no reduction in the per capita consumption since 1907, the daily average consumption for 1916 would have been about 155 000 000 gal.

If the conditions as they existed prior to 1904 had been allowed to continue, additional sources of supply would, without doubt, have been required before the present time. It is also probable that if the act requiring the installation of service meters on all works receiving a supply from the Metropolitan Works had not been enacted, it would have been necessary to construct additional works by 1920.

It was estimated in the report of the Metropolitan Water and Sewerage Board to the Legislature of 1904 that the cost of new works required within the next twenty-five years to supply the probable demand for water if the waste was not checked would be at least $32 000 000, assuming that the district remained as constituted at that time.

The greater the quantity of water used, the more it costs in the end to furnish water to the tap. At a fixed rate the consumer is charged a certain sum and naturally is not directly interested in leaky pipes as long as no damage is caused by the water. The leaks increase in volume and the quantity of water required for legitimate use is running to waste. Wasted water means larger

mains, more pumping machinery, wasted coal and labor, and, finally, extension of works for larger supplies and an increased sewer system to care for the wasted water.

Many are willing to pay for their own and their neighbors' waste by general taxation, but are unwilling to continue to pay for their own waste when presented with a quarterly bill.

The writer believes that water meters are as much a part of a well-operated water-works system as gas or electric meters are to their respective works. Many gas companies account for 80 per cent. of gas delivered through the master meters. The master meters on the distribution system of the Metropolitan works account for practically all the water delivered to the works from the watersheds. Well-managed water works in Europe account for all but 10 per cent. of their supply. Cannot American municipalities do as well?

Waste of water can be divided into two classes, — leakage from mains and waste from service pipes. The first can be stopped by efficient management and the latter by enlisting the consumer's coöperation by giving him a direct pecuniary benefit. It appears to the writer that the best way to get results is to sell the water by measure and to keep the measuring devices in good working condition. The writer maintains that the waste which has been stopped in the Metropolitan Water District of Boston by the installation of service meters has deferred for the present the construction of additional works and reduced the cost of maintaining existing works.

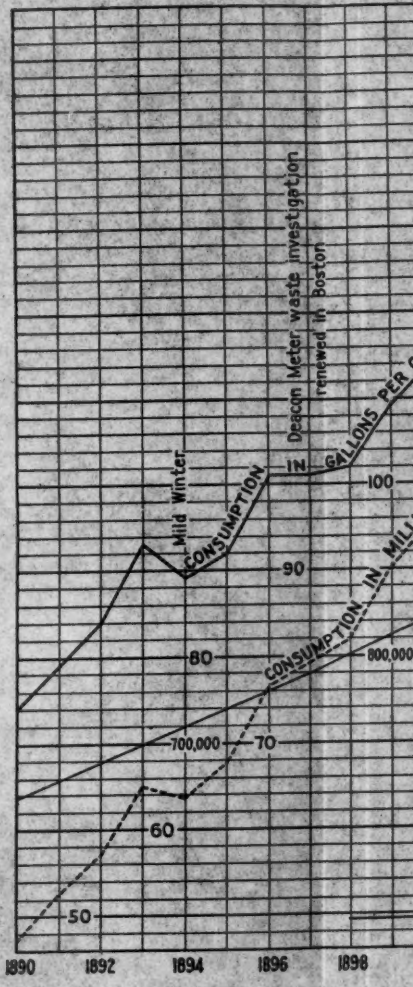
Discussion.

Mr. Frank L. Fuller. This question of night consumption seems to me a very interesting one. Records at Wellesley show that there is a considerable consumption at night, it is a large proportion of the total daily consumption, and it does not seem as though it could all be due to leakage in the pipes, neither does it seem as though it could be due to waste in the houses. Yet it appears to be very difficult of solution.

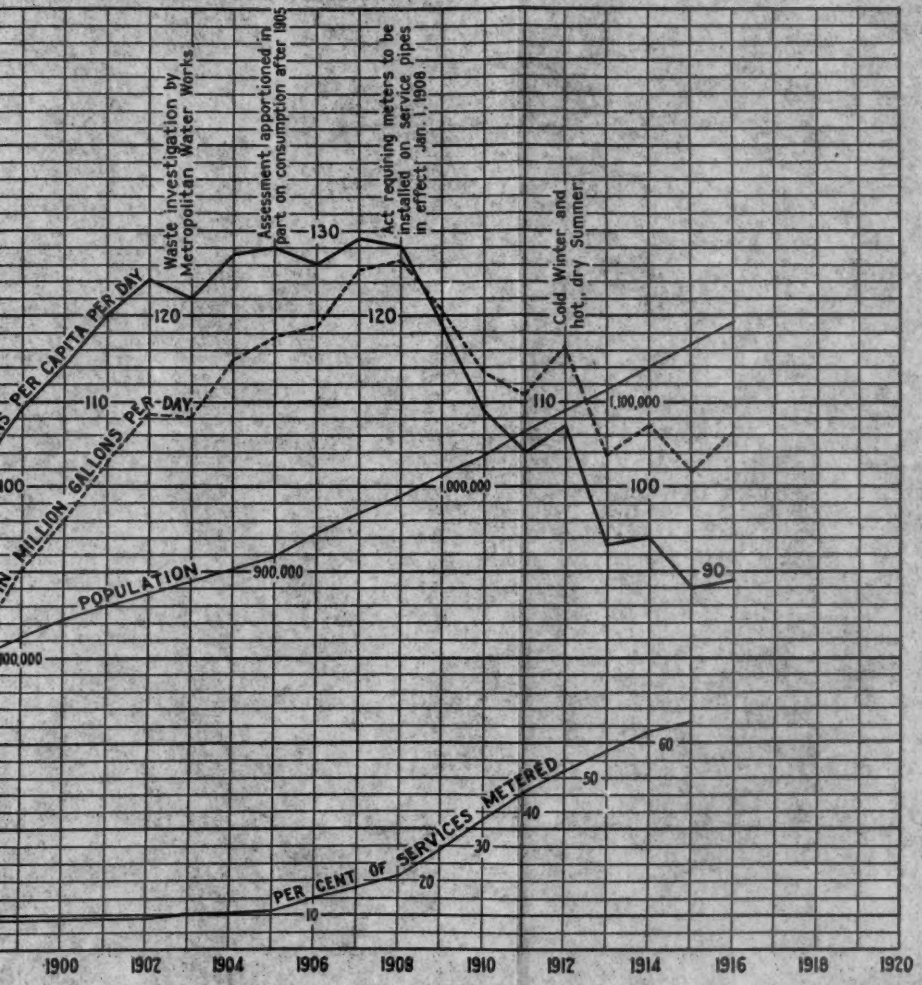
Mr. Killam. It must be one or the other. I think the most interesting work on a distribution system is the accounting for

POPULATION, CONSUMPTIO

METI



TION OF WATER AND PER CENT OF SERVICES METERED
IN THE
ETROPOLITAN WATER DISTRICT
AS SUPPLIED IN 1916
FROM 1890 TO 1916



water delivered into the system. Recently, in a town in the Metropolitan Water District, where the night consumption was high, we divided the town into six sections, and found that most of the water was used or wasted in two of the sections. We will later subdivide those sections into smaller divisions and test the smaller sections until we find the leaks. In the cities and towns supplied from the Metropolitan water district where the services metered are nearly 100 per cent., many of the places are unable to account for 30 per cent. of the water delivered through the master meters.

MR. FULLER. At Wellesley we have everything metered except the drinking fountains, and yet we cannot account for all the water that is pumped. I suppose some of the discrepancy is due to the non-registration of very small flows.

MR. W. A. MCKENZIE. When the state law was passed in regard to the consumer paying for the amount of water used, did that law also carry a provision for minimum rates for various sizes of pipes and services, and different classes of houses? Is the meter rate the same for all residential districts?

MR. KILLAM. It did not. In 1895 the act provided the Metropolitan Water Board should approve the minimum rate established in each municipality, and each city or town is required to submit a minimum rate for approval, which depends on the local requirements, as many of the cities and towns are still under a bonded debt. So there has been no uniform minimum rate established for the entire district.

MR. MCKENZIE. Do you know what those minimum rates are for the same sizes of house services in the residential districts?

MR. KILLAM. The lowest minimum rate is $6 a year for 5 454 cu. ft., equivalent to $0.11 per 100 cu. ft., and the highest minimum rate for 100 cu. ft. is $0.33⅓.

MR. S. H. MCKENZIE. I would like to inquire where they set the meters, — inside or outside the house? If outside, how do you set them?

MR. KILLAM. That is a question for the the local superintendent in the several cities and towns to decide. I see Mr. Merrill, of Somerville, here, and I know he would be very glad to answer that question.

MR. FRANK E. MERRILL. I would say that in Somerville we make a practice, as far as possible, of setting all meters inside, in the cellars of the houses, and as near to the point of entry of the service pipe as possible. There are some cases where it is not convenient to install meters inside the house, and in those cases we set them in the sidewalk, in either a box made of tile pipe with an iron frame and cover, or in a wooden box. Out of 10 000 meters installed in the city, we have 300 outside installations.

PRESIDENT SAVILLE. Are there any other questions? The chair would like to ask Mr. Killam a question. You spoke of the Deacon meters. Are these meters in service now in your district?

MR. KILLAM. They are connected but not in use.

PRESIDENT SAVILLE. You will not use them on your night work?

MR. KILLAM. No. We are using a series of ordinary disk meters and depending on the Venturi meters to measure the consumption in the larger districts.

PRESIDENT SAVILLE. Mr. Fuller, I think, asked a question about the relation of the night loss. Perhaps Mr. Cole would tell us something about that.

MR. E. S. COLE. I don't think I can give you any valuable information on the night rate now. If the night rate is 50 per cent. of the twenty-four hours, we consider it very satisfactory.

PRESIDENT SAVILLE. I think Mr. Fuller's question was whether that night rate, which seems comparatively large, was generally all made up of leakage from services and house connections, or whether a good part might be consumption.

MR. COLE. We find it is a very difficult thing to get the minimum night rate below about 50 per cent. of the average rate.

PRESIDENT SAVILLE. Referring to Mr. Killam's statement about the waste of water in the Metropolitan District, in 1902 and 1903, I have particularly in mind some tests that were made in Melrose, Mass. They had no meters in use at that time, and the distribution system was tested by shutting off the mains in each street. The test showed a consumption of five or six cubic feet a minute on one short street which had about twenty-five houses on it. The leakage was reduced about two thirds by shutting off all the house services at the curb, which meant that two thirds of

the leakage on that street was in the houses themselves. The foreman before shutting off the services listened at each one, and he heard leakage from two of them, and it developed later that one leak was in the gooseneck at the main, and another was between the corporation cock and the house. We repaired the leak at the main, and on a test made the next night we found no leakage. Now, two thirds of the leakage on that street was in the houses and was probably small streams running in closets or from other fixtures in the house. If there had been meters in the houses at that time it would have been interesting to read the meters to see how much of that leakage was registered. I think that follows on Mr. Cole's thought that it is an aggregate of small leaks, small quantities of water that it is hard work to find.

Mr. W. C. Hawley. For several years our company has followed the policy of making an annual Pitometer survey. Our system is divided into districts, so that year by year, as each of those districts is tested, we have the previous tests to go by, as indicating whether or not there has been any material change. Our district is practically 100 per cent. metered. The result is that we find a very low night flow, and yet it is a very considerable flow. And our experience leads us to believe that while a part of it is due to service leaks, and occasionally to a leak at the joint, the most of it is in the houses and is in streams that are too small to be measured by the ordinary water meter. The ordinary water meter that has been in service for a time won't measure a stream running two, three, or four gallons an hour, and that amount in a good many houses soon mounts up to a considerable volume of water. But we do find frequently service leaks, — leaks under service lines running into sewers, or getting away somewhere, that we would never find without the Pitometer. And by making these surveys we have been able to account for from 80 to 82 per cent. of the water that we draw from our r servoir.

Mr. William J. Willson. I might state for the information of the members a little experience in 1911 when we put a Pitometer on the system, by which we stopped a leakage of one million gallons in twenty-four hours. In this case all of the leaks that were found, with one exception, were from abandoned services

under paved streets and the water was running off into the sewers or other structures. The exception was the case of a 16-in. joint, virtually blown out. This experience shows that it is well to cut off abandoned service lines at the mains.

PRESIDENT SAVILLE. Perhaps the speaker would also agree that it would be well not to accede to some of the requests of street departments, where they are going to pave streets, to put in services ahead of the paving, so that you won't have to take the paving up.

MR. H. F. DUNHAM. In regard to leakage on house services. We have had occasion to make a number of Pitometer surveys of our works, and we were very well satisfied when we reduced our night consumption to 30 per cent. of the average. In making these surveys we found that the leaks are generally small leaks. The question has been raised here in regard to keeping the fixtures in the houses in good repair. There is a limit to that in which the property holder, the owner, may be burdened much in excess of the value of the water that is wasted in the fixtures. If a man is paying 20 cents extra, say, upon his monthly bill, it will take a good many monthly bills to pay one plumber's bill, and the question arises whether or not when you ask the consumers to keep their fixtures so that there is no leakage, you are not imposing a burden on your customer which is unnecessary and unreasonable. That is the question that has confronted us a number of times. So that I believe from my experience of many years that if you can reduce your minimum night consumption to 30 per cent. or less of your daily average consumption you have done about all that you can expect to do.

MR. MCKENZIE. I have noticed a large amount of this night consumption has taken place in toilets, and I was wondering whether anybody here had ever made a rule of any kind as to the kind of toilet that should be installed, or has found a valve that can be kept tight for any length of time. Sometimes if you repair them they will stay in repair only a short time. It seems to me that is one thing that might be taken up and a great deal of water saved, if some valve which could be kept tight could be found.

MR. DUNHAM. I would like to ask, while on this subject,

if this matter could not be largely controlled under the conditions under which the works are operated, whether you have a high pressure or low pressure. I will say that we have had a condition that was rather unusual and rather hard on the fixtures. We carry a pressure of about 60 lb. We furnish a direct fire pressure for every alarm, and that pressure is raised from 60 to 110. The result is that these fixtures get a great shock, sometimes three or four times a day, and we have a much higher leakage than if we could maintain a constant pressure.

PROCEEDINGS.

Thirty-Sixth Annual Convention.

Hartford, Conn.,
September 11, 12, 13, 14, 1917.

The thirty-sixth annual convention of the New England Water Works Association was held at Hartford, Conn., September 11, 12, 13, and 14, 1917.

The sessions of the convention were held in Unity Hall, Pratt Street, where also were provided accommodations for the exhibits of Associates.

The following members and guests were present:

Honorary Members.

Frank E. Hall. George A. Stacy. R. J. Thomas. — 3.

Members.

G. H. Abbott.	L. G. Carlton.	A. B. Farnham.
J. M. Anderson.	C. E. Chandler.	C. A. Farnham.
F. E. Appleton.	E. S. Cole.	A. D. Flinn.
M. N. Baker.	P. J. Conlon.	A. P. Folwell.
L. M. Bancroft.	H. R. Cooper.	H. F. Frost.
Stephen Barden.	G. K. Crandall.	F. L. Fuller.
C. F. Barker.	H. C. Crowell.	F. C. Gamwell.
H. K. Barrows.	A. W. Cuddeback.	W. A. Gardner.
G. W. Batchelder.	John Cullen.	Patrick Gear.
G. H. Bean.	F. A. Darling.	H. T. Gidley.
F. D. Berry.	M. W. Davenport.	F. J. Gifford.
F. E. Bisbee.	C. E. Davis.	T. C. Gleason.
A. E. Blackmer.	F. J. Davis.	H. J. Goodale.
C. M. Blair.	J. M. Diven.	F. S. Goodwin.
Bertram Brewer.	John Doyle.	S. M. Gray.
T. L. Bristol.	H. F. Dunham.	L. M. Hastings.
H. R. Buck.	J. S. Dunwoody.	E. L. Hatch.
Alvin Bugbee.	C. W. Eddy.	A. R. Hathaway.
E. L. Burnap.	E. D. Eldredge.	W. C. Hawley.
L. W. Burt.	R. H. Ellis.	A. B. Hill.
C. J. Callahan.	W. B. Ellis.	T. E. Hopkins.

J. L. Howard.
W. F. Howland.
H. W. Horne.
J. A. Hoy.
J. L. Hyde.
J. F. Jackson.
A. W. Jepson.
G. A. Johnson.
W. E. Johnson.
W. S. Johnson.
T. N. Kapoustine.
Willard Kent.
J. A. Kienle.
S. E. Killam.
A. C. King.
G. A. King.
H. M. King.
G. H. Leland.
M. B. Litch.
B. C. Little.
E. L. Lockridge.
F. H. Luce.
P. J. Lucey.
S. H. MacKenzie.
H. V. Macksey.
E. T. McDowell.
C. R. McFarland.
Thomas McKenzie.
W. A. McKenzie.
J. N. McKernan.
Hugh McLean.
A. E. Martin.
J. H. Martin.
T. P. Martin.
J. H. Mendell.
F. E. Merrill.
G. F. Merrill.
Alexander Milne.
H. A. Miller.
M. L. Miller.
E. E. Minor.
P. T. Mullin.
J. A. Newlands.
R. J. Newsom.
F. L. Northrop.
W. H. O'Brien.
E. M. Peck.
A. E. Pickup.
J. F. Ranger.
W. H. Richards.
L. C. Robinson.
P. R. Sanders.
C. M. Saville.
A. L. Sawyer.
W. P. Schwabe.
J. E. Sheldon.
M. A. Sinclair.
E. W. Smith.
G. H. Snell.
H. T. Sparks.
F. N. Speller.
H. C. Stevens.
E. L. Stone.
J. F. Sullivan.
W. F. Sullivan.
G. A. Taber.
A. T. Thompson.
J. L. Tighe.
E. J. Titcomb.
R. K. Tomlin, Jr.
D. N. Tower.
F. M. Travis.
Louis Treal.
H. R. Turner.
C. H. Tuttle.
J. H. Walsh.
R. S. Weston.
R. C. Wheeler.
F. H. White.
J. G. Whitman.
R. W. Wigmore.
W. A. Wilcox.
W. J. Willson.
I. S. Wood.
L. C. Wright. — 148.

ASSOCIATES.

Allen & Reed, Inc., Z. M. Jenks.
American Bitumastic Enamels Co., F. G. Ricker.
The American City, J. H. Van Buren, T. R. Kendall.
Builders Iron Foundry, A. B. Coulters, F. N. Connet.
Carbic Mfg. Co., E. G. Frey.
Central Brass Mfg. Co., M. J. Hirschfield, Joseph Mayer, R. M. Corcoran, V. J. Mahler.
Central Foundry Co., R. W. Conrow, Stuart Root, W. H. Feltt, H. Y. Carsons.
Chapman Valve Mfg. Co., V. N. Bengle, C. E. Pratt, H. U. Storrs.
Chicago Pneumatic Tool Co., H. W. Buker.
Darling Pump & Mfg. Co., Ltd., H. D. Thorp, H. A. Snyder.
Dixon Crucible Co., Joseph, H. A. Nealley, C. A. Shaw.
Eddy Valve Co., H. R. Prescott, H. A. Holmes.
Edson Mfg. Co., H. L. B. Watson.
Engineering News-Record, I. S. Holbrook, Wm. Buxman.

Fire and Water Engineering, I. H. Case, Fred Shepperd.
Garlock Packing Co., F. S. Bulkley.
Goulds Mfg. Co., The, C. W. Fulton.
Hayes Pump Machinery Co., J. H. Hayes.
Hersey Mfg. Co., J. H. Smith, W. A. Hersey, W. C. Sherwood.
Kennedy Valve Co., M. J. Brosnan.
Leadite Co., The, George McKay, Jr., J. P. McKay.
Lead Lined Iron Pipe Co., F. N. Du Bois, T. E. Dwyer.
Lock Joint Pipe Co., G. C. Bartram.
Ludlow Valve Mfg. Co., A. R. Taylor, J. H. Caldwell.
Mueller, H., Mfg. Co., W. N. Fairfield, G. A. Caldwell.
Municipal Journal, J. T. Morris, J. L. Collins.
National Meter Co., J. G. Lufkin, H. L. Weston.
National Tube Co., H. T. Miller.
National Water Main Co., B. B. Hodgman.
Neptune Meter Co., H. H. Kinsey, T. D. Faulks, Charles Bachmann.
Norwood Engineering Co., H. W. Hosford, F. M. Sears, H. G. Meuke.
Pitometer Co., The, E. D. Case.
Pittsburgh Meter Co., T. C. Clifford, J. W. Turner, V. E. Arnold.
Pratt & Cady Co., Inc., E. L. King, W. D. Cashin, O. L. Beach, M. R. Cook.
Rensselaer Valve Co., C. L. Brown, I. A. Rowe, J. S. Warde, Jr.
Ross Valve Mfg. Co., William Ross.
Schramm & Son, Chris D., J. W. Gleason.
S. E. T. Valve & Hydrant Co., C. L. Lincoln, P. B. Madden.
A. P. Smith Mfg. Co., F. L. Northrop, D. F. O'Brien, A. C. Nieman, T. F. Halpin.
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Water Works Equipment Co., W. H. Van Winkle, W. H. Van Winkle, Jr.
Wood, R. D., & Co., C. H. Becker, C. R. Wood.
Worthington Pump & Machinery Corp., Samuel Harrison, W. F. Bird. — 94.

Guests.

Maine.

Lewiston, Gertrude Callahan, Helen Callahan.

New Hampshire.

Derry, Mrs. G. H. Bean.
Manchester, Mrs. J. H. Mendell, G. A. Woolner.
Nashua, Mrs. W. F. Sullivan.

Massachusetts.

Boston, H. A. Burnham, Mrs. G. A. Caldwell, Mrs. C. W. Fulton, Mrs. W. S. Johnson, Mrs. S. E. Killam, R. M. Kinsman, G. H. Richey.
Cambridge, Mrs. L. M. Hastings.
Cohasset, Mrs. D. N. Tower, Miss M. P. Tower.

Florence, W. G. Ryan.
Framingham, Mrs. W. F. Howland.
Franklin, Miss Kathleen Darling.
Greenfield, Mrs. G. F. Merrill, W. T. Noyes.
Haverhill, H. B. Crowell, F. T. Hamlin, W. A. Tweed.
Holyoke, L. W. Bacon, Mrs. Hugh McLean, Miss Marion McLean, Mrs. J. F. Ranger, Mrs. J. E. Sheldon.
Lowell, Mrs. F. E. Appleton, J. E. Sullivan.
Marlborough, Mrs. G. A. Stacy.
Melrose, Mrs. J. L. Howard.
Onset, Neddie Eldredge.
Palmer, Mrs. F. C. Gamwell.
Pittsfield, Mrs. A. B. Farnham.
Plymouth, Mrs. E. A. Blackmer.
Reading, Mrs. L. M. Bancroft.
Southbridge, Mrs. C. H. Abbott.
Springfield, Mrs. H. M. King, W. E. Moore, May Potter, Mary A. Shea, C. W. Winslow.
Ware, Mrs. John Gleason.
Wellesley, Mrs. F. L. Fuller.
West Springfield, W. H. Bagg, B. E. Fox, G. N. Norris, J. F. Whitney.
West Brookfield, J. E. Malloy.
Woburn, Mrs. H. V. Macksey.
Worcester, Mrs. John Doyle, W. H. Larrabee.

RHODE ISLAND.

Narragansett Pier, Mrs. Willard Kent.
Providence, G. F. Hiller.
Westerly, Mrs. Thomas McKenzie.
Woonsocket, Mrs. Z. M. Jenks.

CONNECTICUT.

Ansonia, Mrs. F. J. Davis.
Bristol, D. F. Crowley.
Bridgeport, Mary A. Martin.
Bristol, C. L. Wooding.
Danbury, T. S. Durant.
East Hartford, Charles Barnes, Mr. and Mrs. Albert Clay, Mrs. James Fogarty, Miss Annie Fogarty, Miss Nellie Fogarty, L. S. Forbes, James Johnston, E. E. King, Mrs. Joseph Walsh, Mrs. J. H. Walsh, Miss Madeline Walsh, George Westbrook.
Hartford, A. H. Blease, F. S. Brainard, J. A. Collord, W. J. Crawford, Harold Evans, Arthur Fifoot, E. J. Flynn, H. R. Freeman, W. F. Gunn, R. F. Hazard, A. E. Knowlton, J. A. Lawler, Miss E. L. Mulcahy, Miss Christine Newton, Miss S. I. O'Brien, Charles E. Rogers, Charles Rogers, Mandel Sener, F. E. Shea, J. J. Sheedy, C. D. Sherman, D. J. Sullivan.
Meriden, Clarence Carpenter, Mr. and Mrs. J. B. Gleason, J. W. Holden, J. A. Tower.
Middletown, J. J. Griffin, Mrs. Harry Mayoll.
New Britain, T. H. Kehoe, W. B. Rossberg, J. H. Towers.
New Canaan, Ben Keeler.
New London, Mrs. G. K. Crandall, S. C. Starr, G. E. Watters.
New Haven, Mrs. C. M. Blair, L. D. Burke, Mrs. J. F. Dorrigan, Mrs. J. F. Jackson, Miss Anna C. Lee, Lloyd Logan, E. A. Toole.
Norwich, Mrs. E. L. Burnap, Mrs. C. E. Chandler.
Plainville, Mr. and Mrs. E. H. Hills, Mrs. J. N. McKernan.
Rockville, Mrs. A. T. Thompson, Robert C. Thompson.
Southington, Miss Eleanore MacKenzie, Miss E. J. MacKenzie, Miss F. L. MacKenzie, Mrs. S. H. MacKenzie, D. F. Shanahan.
Stamford, B. H. Keeler.
Thompsonville, C. A. Goodhue, Richard Norris, Mrs. W. P. Schwabe.

Torrington, W. E. French.
Wallingford, J. P. Bridgett, J. E. Martin, Mrs. W. A. MacKenzie, A. E. Sutterlin.
Windsor, P. F. Ellsworth, Mr. and Mrs. J. A. Oaks, Mrs. W. P. Mott, Mrs. H. R. Turner.

NEW YORK.

New York City, W. F. Barnwell, Mr. and Mrs. H. B. Coho, P. P. Dean, Ellis Hyers, J. J. Walsh, D. F. Wilcox.

NEW JERSEY.

Montclair, Mrs. W. C. Sherwood.
Newark, James Woolley.

PENNSYLVANIA.

Erie, G. C. Gensheimer.
Philadelphia, W. W. MacCallum, E. W. Nichols, Miss Anna Nichols,
Steelton, Mrs. M. B. Litch.

OHIO.

Youngstown, Mrs. T. S. Chamberlain.

ILLINOIS.

Evanstown, John Gaitenby.

NEW BRUNSWICK.

St. John, E. J. Terry. — 160.

TUESDAY, SEPTEMBER 11, AFTERNOON SESSION.

The convention was called to order at 2 P.M. by Caleb Mills Saville, the President. In opening the convention President Saville spoke as follows:

Gentlemen, — This is the opening of the thirty-sixth annual convention of the New England Water Works Association, and greeting us here are representative men of the city of Hartford, — men of local prominence and also those whose names are of national significance in the field of politics, law, literature, and business. Hartford is preëminently a business man's city, and out of the very midst of its bustle and work these men, representative of scores of others, have come to give us welcome.

Personal traits often are accentuated by public life, and trial in this furnace is one of the most severe tests of human character. We, therefore, greatly respect him who comes forth upright and unsmirched, especially when moved as by an irresistible impulse to do things not for personal glory but for the good of the community. Such a man is he whom I now have honor in presenting to you, — lawyer, progressive official, exponent of the highest type of public servant, — the Hon. Frank A. Hagarty, mayor of the city of Hartford.

ADDRESS OF WELCOME BY HON. F. A. HAGARTY.

Mr. President, Ladies and Gentlemen, — I thank your chairman for this very flattering presentation to you. It is only the kind of thing, however, which we have come to naturally expect from the amiable and capable manager and superintendent of our local water system.

It is a very great pleasure indeed, in behalf of this municipality and its people, to bid the members, the delegates, and their friends of this New England Water Works Association a cordial welcome to the city of Hartford. We always take pleasure in bidding a welcome within our gates to men or women who are banded together for a patriotic or a useful purpose, and it is particularly gratifying to us to have this opportunity to offer a welcome to you who are interested in a work which is so near to all of the people who live in the large centers of population throughout the country.

In these troublous times through which we are now passing and through which the world is passing, the conventions do not always show what they advertise beforehand; but we have no hesitation in bidding you welcome, because we know that no seditious word, no word other than words of patriotism, so far as they relate to our country and the crisis through which it is passing, will be heard in this convention. And that ought to be true of every convention that is convened in any corner of this country during this crisis.

The people who live in the larger centers of population, not only in this country but in every civilized country, have become so used to taking as a matter of course the various facilities which make it possible for urban populations to live as they do, that they scarcely stop to think, to count, if you please, the things that go to make it possible to live in a community like Hartford, — such things as proper transportation facilities, gas and electric power, and perhaps more important than any other, an abundant supply of pure water. Without an abundant supply of pure water it would be practically impossible for these municipalities which exist in every state of our country to live the kind of a life that their people do live in this twentieth century.

And so the business that you are engaged in fostering and in studying and in trying to make better is, perhaps, the most important feature of community life; and because this is so it is doubly a privilege and a pleasure to bid you welcome to this fair city, which was one of the pioneer communities of this country in the establishment of a municipal water system. I will not go into that this afternoon further than to record the fact that before the century which preceded the present one had begun there had been established here, on a small scale to be sure, a water-works system. Along in the middle of the last century — of the nineteenth century — there was projected and built a splendid water-works system which supplied our city for the next fifty or sixty years, and at the present time we are engaged, under the able management of our present board of water commissioners, and under the able guidance of your honored President as manager, in the construction of a very much more extensive water system, which is to be brought to us over many miles of country and which is to cost from two to three millions of dollars. When it has been completed it is expected that it will adequately supply the wants of the people of Hartford and of its varied industries of many kinds for the next fifty or sixty years. And it seems to me particularly opportune that you should come here at this time when we have these works in the course of construction. It may very well be that some suggestion which may arise out of your visit here will prove of large benefit to our people and to our community so far as this particular work in which we are now so much interested is concerned. But, however that may be, it cannot but result that a gathering of this kind will bring together the various communities which you represent in this organization. The exchange of ideas which is brought about by gatherings of this kind cannot fail to be fruitful of good results.

I hope that you will find this convention place which you have chosen, this city which you have chosen as your convention place, as pleasant as the cities which you have become used to as convention places. We who live here in the city of Hartford, and have lived here all our lives, naturally think that this is the most beautiful city that can be found anywhere. There are undoubtedly ladies and gentlemen here who are familiar with the best cities on

this continent, and other continents as well, and I will only say in passing that during your sojourn here I hope, and the people of Hartford hope, that you will at least find Hartford a pleasant city in which to hold your convention.

And so, gentlemen, not to detain you from the proceedings of the afternoon session, I will conclude by again saying that it is a very great pleasure to welcome you to the city of Hartford, to express the hope that your deliberations will be profitable to yourselves and to the communities which you represent, and that when you go you will take away with you such pleasant impressions of the city of Hartford and its people that you will be constrained to pick out the capital city of the state of Connecticut as a place for holding some future convention of your Association. [*Applause.*]

PRESIDENT SAVILLE. The president and editor of the oldest daily newspaper in America, a man of strong principle and of the highest character, trustee and overseer of Yale University, exponent of the literati of America, — I take the greatest pleasure in introducing the Hon. Charles Hopkins Clark.

ADDRESS OF WELCOME BY HON. CHARLES HOPKINS CLARK.

Mr. President, Ladies and Gentlemen, — When I have recovered from the blushes that the chairman placed upon me I will say a few words, if you please. I am very glad to join in the welcome to you all here to Hartford, and I am especially glad that our system of water works is going to be inspected by a body of such intelligent experts as you gentlemen here. I do not fear at all what your verdict will be. Hartford is a progressive city and up-to-date in all respects, and I am confident that the result of your inspection will be to add new force in that direction.

I am here, as Mr. Saville has said, to-day simply because I have an hereditary connection with the business. Hartford decided, back in 1854, to establish municipal water works, and my father was the president of the first board of commissioners, and they built a reservoir up on Asylum Hill, — the highest available land, — to which they pumped up the pure water of the Connecticut River; and then they sent it back again defiled and polluted, to the distress of our neighbors farther down the stream. Well, that was 1854, but it was not long before they found that that

was going to be inadequate to the demands of the growing city, and they decided to pond the whole watershed of the West Hartford Hills, out beyond us here, which you will see during your visit. The first reservoir was built there in 1865. There is now a chain of reservoirs, — six altogether, — ponding at different places the water from these streams that come together there. The trouble with ponded water is that you have to have such an enormous quantity of it. What with the evaporation which is going on all the while, — and which is worse during a drought than any other time, — and with the occasional droughts which we have here, it became evident before long that we had got to have something greater than all the water that could be stored there. My father came into the presidency of the board a second time in 1882 and remained there until his retirement in 1895, being eighty years old and through with business. How many of those reservoirs out there he built, I don't know; but I do know that he laid out and constructed the reservoir park, which I hope you will all see, and which seems to me an adequate monument for any man's service to the city. It is one of our beauty spots.

In the way of business, the city of Hartford adopted the plan of compelling every customer to use a water meter. Now, I understand there are places where that is not done, where you pay so much for all the water you use. Suppose that they did that with gas, suppose they did that with electricity, — it is an utterly unbusinesslike method. And they adopted the plan here — which is straight business — of paying for what you get. Mr. Saville has shown me a chart showing that at the time that rule was adopted Hartford was using seventy-nine to eighty gallons of water per capita per day, and to-day it is using only sixty-six gallons per capita per day, a saving of thirteen or fourteen gallons a day for each person, which in a large city like this means an immense amount of water saved.

It became evident that, with the evaporation and with the need of pumping from the river, we had to do something more, and not long ago the great scheme at Nepaug, which you will inspect on Friday, was developed, and it is approaching completion. I am very glad that such a body of intelligent men is going to see it, and I am sure you will be impressed by it. Hartford is bound

to have enough water. Recent legislation at Washington indicates that there will be some increase in its use whether the population increases or not. [*Laughter.*]

Now, I asked Mr. Saville in regard to the fact of the development of water works. Hartford had a water-works system back before 1800. Occasionally in their work they would dig up a hollow log, and they would find that it was a part of a system for supplying water through hollow logs. And I believe they had one or two similar private companies in other cities. But Hartford was the first city hereabouts that undertook water works with the iron supply pipes and the paraphernalia that goes with it. Hartford established them in 1854, New Haven established a private company in 1860. The New Haven company to-day is very prosperous, gives plenty of water, good water, and is successful in all respects. But it is a creature of slow growth.

My friend Mr. Gross, here, and I were in college together. I graduated from Yale in 1871, and I up to that time did not know there was a system in New Haven. The Yale College boys depended on the old college pump, and the water from the old college pump was never analyzed, although its results were abundant, because a part of the course there was typhoid fever. [*Laughter.*]

Waterbury established water works in 1868, Providence in 1870, New London in 1872, Springfield in 1873. So that here again is evidence of the progressive spirit of Hartford.

Now, it is your business to see that communities have adequate good water supplies. But that is not the end of the business. Before 1854 Hartford had about forty sewers which carried off the extra surface water from storms; to-day we have one hundred and ten miles of streets, and the city engineer tells me that there is a sewer in nearly every street in the city. Think what that means. All the one hundred miles or more of pipe used every day to pour filth into the Connecticut River! And what Hartford is doing, every other city is doing, and the Connecticut River is to-day an open sewer for the Connecticut Valley; and all the other rivers we have in this state are doing the dirty part in that work. Somebody has got to come along who will get at the other end of the proposition, who will take the sewerage and put it into fit shape to be used again, who will purify the water and get

back on to the land that which the land needs. I have the feeling that the convention which is to be held here will tend strongly to bring about that result, — that we will get back on to the land that which the land needs, resulting not only in giving us purer water, but in improving the soil and giving us cheaper foods.

I thank you, gentlemen, for your attention, and I hope you will follow out the mayor's suggestion and see all you can of Hartford. We are very modest people, but I do venture to say that the more you see of Hartford the more you will think of it. We shall be very grateful to you for any good opinions that you carry away. [*Applause.*]

PRESIDENT SAVILLE. A distinguished jurist, president of the Connecticut Bar Association, sagacious man of business, reliable and trusted adviser, a man whose friends are legion and whose life exemplifies the highest ideals and standards, — I am honored in presenting to you the Hon. Charles E. Gross.

ADDRESS OF WELCOME BY HON. CHARLES E. GROSS.

MR. GROSS. *Mr. President, Gentlemen of the Water Works Convention, and Ladies,* — I have made a mistake, Mr. President, at the very opening. I am embarrassed in my opening sentence. And that reminds me that a short time ago I was present at a dinner where there were twenty-two young ladies, where the Rev. Joseph Hopkins Twitchell spoke. And when Mr. Twitchell commenced his address he said, " Gentlemen and ladies." Then he said, " Now, I am in it." And that reminded him of a story in a grammar class. The end of the week had come and the teacher wanted to review what she had attempted to teach the children during the week. And she had the girls and boys before her, and she said to them, " Now, I am going to give you some sentences which will have grammatical errors in them, and I want you to point them out. For instance, ' The horse and the cow is in the pasture.' " No one raised a hand. " Why," she said, " don't any of you see any grammatical error there? Let me give it to you again. ' The horse and the cow is in the pasture.' " One little fellow raised his hand and she said, " Jimmy, where is the mistake? " He said, " The lady should have been mentioned first." [*Laughter.*]

And, Mr. Chairman, you have also embarrassed me by your introduction — I should not have known to whom you referred had it not been the mention of my own name. But you will all, I think, recognize that, like another very distinguished engineer — the late Hopkinson Smith — your President is an artist along many lines, and to-day he has commenced by being a creator of fiction, — if you will pardon me.

Now, I expected a very different introduction than he gave, — a very different one. I supposed that I was invited here possibly as the oldest native inhabitant, who can tell you of the conditions here in Hartford before the father of my distinguished friend wrested us from it in 1854. Or I thought possibly I might be introduced as one of the "goats." Now, I am a lawyer, and you know lawyers are divided up into classes according to the special work that they do. We have counsel, and we have barristers. A barrister is one, as you know, who tries out questions of fact in the courts. Possibly you never heard the difference between a counsellor and a barrister. If you never heard the answer, I will tell you. Some one said that the difference was exactly the same as between a goat and a bulldog, — one fought with his head and the other with his mouth. [*Laughter.*] Now, my firm for the past generation has been counsel for the Board of Water Commissioners of Hartford, and although the work of fighting has been done by my partners, yet I claim to be enrolled in the class of goats. But possibly when you know that my special study has been hydraulics, you will say that I do not belong in the class of goats but should be classed by myself as a ram. [*Laughter.*]

I said I expected to have been introduced to you as the oldest native inhabitant, and so I had prepared to tell you of the conditions here in Hartford before the organization of the Board of Water Commissioners. I could have told you of the old public cisterns along our highways for fire purposes, also the old cistern which was connected with every dwelling house, where they collected the rain water from the roofs for culinary and laundry purposes. I could have told you of the old deep wells with the cold water many feet down, and which wells were also used as refrigerators in the summertime, where the cream and the milk and the meat were kept, being lowered in a basket to near the water's edge, for their preservation during the hot season.

And then following along later I could have told you of many things that preceded the formation of our water works, — how the distinguished Dr. Bushnell had a far-sighted vision of making along the banks of the Connecticut River a modern Manchester of England, for, with the aid of engineers, his proposition was to turn the entire ordinary flow of the Connecticut River into a large canal, extending from the Enfield Falls to Hartford, along the line of which were to be numberless hydraulic sites, and occasionally a water reservoir for the community for drinking water. And into those reservoirs he proposed to force the water from the canal by means of pumps in wheel-pits, which were to be fed from the canal, and power generated for driving the pumps. Now, that was a great vision; it was worthy of the great man that he was. But in 1840 the conservative investors of this section could not see the return for their enormous expenditure of money.

Then I could have told you of the vicissitudes of the earlier boards of commissioners, the criticism that they were constantly subjected to, the injunctions which stopped their work from time to time, the demand for other reservoirs within our city limits, or greater pumps, and later the urgent demand for a more sanitary supply of water.

And so we built the reservoir in West Hartford, and shortly after the completion of the second, and shortly after the water was turned on in 1867, came the destruction of those reservoirs, and all the trouble that followed thereafter. And, as Mr. Clark has told you, that initial reservoir grew in number to six, and still we are not satisfied. We demanded more water, more water, more water. And how that demand has been met I trust you will all have the privilege of seeing for yourselves later in the week, and I am satisfied that your opinion will be that, as to this new system of water, Hartford is up to date.

Now, good water works are the best physical asset that a city can have, and I am satisfied that the value of the Nepaug system to the city of Hartford will never depreciate until the Martians come here and instruct us as to their skill in building waterways. But I think we must not be contented with this system which we have to-day; I think there is a greater question that necessarily must be taken up soon by all cities. I think the conflagra-

tion in San Francisco has taught us the danger of a city depending upon a pipe line entirely for water. We know that the line from Nepaug comes through trap-rock which once was subjected to volcanic action. And as the earth cools — I don't know when or how soon — we shall have another upheaval, and what will be the result to the pipe line from Nepaug, I don't know. I think every city should have a dual system. I think we should have one system for household purposes and another system for the manufacturers, for fire hydrants, for street cleaning. I do not believe that the good water from Nepaug should be used for any such purpose. In fact, I never see Poland water used for washing the piazza of the hotel there but that I think it is a criminal waste. And, as I said before, we should be independent of a pipe line which comes as many miles as that from Nepaug. We have here in Hartford the Connecticut River; we have already a very large pumping station; we have a reservoir on the hill, as Mr. Clark has said, at our highest peak; we have mains that very soon, I think, will have to be discarded for new mains because the pressure of the water from the west will be so great. Now, I do hope that our pumping station will never be sold. I trust that those mains in our streets will never be taken up nor the Garden Street reservoir leveled. I want them all preserved so that we can have within our limits fire protection and a creditable supply of water for the baser uses.

You may say to me that we should be thankful for what we have got. We are. We rejoice at this new system which has just been completed. And we rejoice that within a very few weeks there will be no need in Hartford of our asking for Apollinaris water, nor French, Italian, or even Poland. We shall have to offer to every guest within our gates a glass of pure, cold water from Nepaug, and I am satisfied that when that water is drawn no one will have cause to complain that the distilleries stopped business last Saturday night. [*Laughter.*]

Now, who has brought us to this very happy condition? When this Nepaug work was first mapped out, every one saw that it would be necessary to secure the services of not only a competent engineer, but one who could also be said to be an artist in his line. There was only one place then open to find such a man, — the

congregation of eminent engineers was at Panama, and we went there. We found in that glorious Southern Cross a star of great magnitude, and, following the motto of our state, we translated that star from the Southern Cross to the northern Dipper in order that he might furnish a greater supply of water to Hartford. Now, we know that what is well begun is half done already. Mr. Saville, your President, in a few days will take great pleasure and pride, and justly so, in showing you the development of the Nepaug system; but, gentlemen, I take greater pride this afternoon in telling you that the successful execution of that great work is due to your President, Mr. Saville. [*Applause.*]

PRESIDENT SAVILLE. I think that my friend, Mr. Gross, has put the matter of embarrassment the other way, if you please. He told you how embarrassed he was and what he thought of what had been said about him. You can only judge from that how to take his own words. He told you what he could tell you about; he doesn't tell you about what he can tell you about. That is, how one of the largest hydraulic propositions in the country — the Holyoke Water Power Company, of which he is president — has expanded under his able management.

Progressive and able man of business, open-minded and keen in judgment, upright and clean in all his dealings, excellent representative of the men whom Hartford calls to administer her municipal business,— I take pleasure in presenting to you Mr. James P. Berry, acting president of the Board of Water Commissioners.

ADDRESS OF WELCOME BY MR. JAMES P. BERRY.

MR. BERRY. *Mr. Chairman and Gentlemen,* — In the absence of the President of the Board of Water Commissioners, Mr. Frank E. Howard, I have been asked to come here this afternoon and extend to you gentlemen a cordial greeting, and to earnestly request that each and every one of you will pay a visit next Friday to our water-works system in West Hartford, for, aside from the social character of your organization, there certainly is a more serious side, that being the coöperation given, individually and collectively, by this organization to one another in the furtherance of up-to-date systems of water conservation and distribution.

I am connected with the Board of Water Commissioners here for a period of only a very few weeks, and my experience here has impressed me with the fact that the citizens of Hartford know very little indeed about the magnitude of the work that has been carried on here during the last few years in the perfecting of their water system. It was my privilege in my early days to be a member of the Common Council of the City of Hartford, and during those days I witnessed the vicissitudes of Mr. Clark, the father of the Hon. Charles Hopkins Clark, whom we have with us here to-day, in his determination to not only install but to extend and maintain a system of water works for the city of Hartford. I have read of the work that the different boards of water commissioners have put through in order to secure proper legislative action to permit them to further the project now in hand, — the condemnation proceedings, the issuance of bonds, and, in fact, everything in connection with the work; but until I had an opportunity recently to go out and make a close inspection of our present system of water works I had no idea nor conception whatever of the magnitude of those works. You gentlemen no doubt will favor us by a visit out there this week, and we respectfully ask that you carefully inspect those works. The good things that you see about them you can carry back to your homes to advertise the system of the city of Hartford, and its defects you can make known to Mr. Saville.

None of us can fail to have been impressed in the last few years with the extensive work that has been carried on by federal, state, and municipal governments in order to solve the problem of pure food. Your vocation is far above this problem, for you are engaged in the conservation and delivery into the homes of the municipalities in the commonwealths which you serve God Almighty's health-giving, sustaining, and healing blessing, — pure water. Gentlemen, I thank you. [*Applause.*]

PRESIDENT SAVILLE. Able journalist, independent in thought and speech, ardent and conscientious advocate of civic progress, indefatigable worker for public welfare, and efficient president of the Chamber of Commerce, — Mr. Frank G. Macomber.

ADDRESS OF WELCOME BY FRANK G. MACOMBER.

MR. MACOMBER. *Mr. President, Ladies and Gentlemen,* — When we were coming into the hall I suggested to your President that he had an aggregation that was sufficient to allow me to drop out, — that I appeared to be sort of an "also ran." He insisted that I was not, but in opening the meeting this afternoon I noted that he unconsciously agreed with me. He said that you had been honored by having gentlemen come here prominent in the city and the nation as jurists, in literature, in politics, and in business; and then he proceeded to introduce me as a journalist, which lets me out. [*Laughter.*] I can't class in any one of those.

This summer — in fact, only three weeks ago — I came to the very keen realization of how important is the work which you gentlemen do. I spent my vacation on Lake Keuka in the central part of New York State. Out there they say the lake is twenty-four miles long, three miles wide, and eight miles deep, and they have no water works. When I got up in the morning I used to chase down to the lake to get a pail of water, and I hadn't any more than got that pail of water up to the house than my wife would say that she wanted another one. I spent two very pleasant weeks carrying water from early morning until late at night, and from the amount of water I carried I distinctly question the figures which Mr. Clark gave here a few minutes ago as to the consumption of water in Hartford. He said that when there were not any meters the consumption was eighty-odd gallons of water per day per capita, and that since they have installed the meters it has dropped down to some sixty-odd gallons per day per capita. There were five of us in our family at the cottage, and I am very sure that I carried upwards of five hundred gallons of water a day. [*Laughter.*]

I also think that Mr. Clark in giving you those figures furnished a condemnation of your Association and all that it stands for. I was not in Hartford back in the days when there were no meters; in fact, I was a little too young, I believe, to know much about water in those days, but since I have come to Hartford, I have found it necessary in the course of my business to examine from time to time the very interesting old files of the *Courant*, which Mr. Clark edits, and a very careful examination of the news

columns of those papers back in the early eighties demonstrates to my entire satisfaction that Hartford was not a clean town. [*Laughter.*] Yet they used eighty gallons of water per capita per day. Now we are only using sixty-six gallons of water, and it is a great deal better town than it was back when we put the meters in. We are going to demonstrate that to you during the next four days.

We who live here in Hartford — although I am only here with a twelve-year grip on it — we who live here in Hartford, as Mr. Clark and Mr. Gross have told you, are very proud of the city. They say we are very modest about it. We are not modest about it; we blow about it all the time, and we have a right to, and you are going to go away and say we have a right to. You have come to one of the most beautiful cities in the world, and you are going away and tell your friends that when we boast of Hartford we are modest in our boasting, but not modest about Hartford.

I come as the representative of the Chamber of Commerce, ladies and gentlemen, — a commercial body in the city numbering a thousand members, — and for each of those members I wish to give you a most hearty welcome. We want you to have a good time while you are in Hartford, as well as a profitable time, and we are going to do everything we know how to do to have both of these come true. I trust that, as the days go by while you are with us, if you notice anything that seems to be amiss you will call me up and let me know about it, and we will try to correct it right away.

I have said to other conventions that have met in Hartford, at which Mayor Hagarty has spoken, that he gives you the official welcome to this city and the official keys. I wish to say to you that, as a newspaper man and a modest follower in the footsteps of Mr. Clark, I extend to you through the Chamber of Commerce those other keys which you may need and which the mayor officially can't know anything about. [*Laughter and applause.*]

The President announced that the first business in order was the election of members. The Secretary read the following names of applicants for membership, all of whom had been approved by the Executive Committee:

Active — C. B. Crowell, Brattleboro, Vt., president and treasurer of the Brattleboro Water Works Company; Alexander Milne, St. Catharines, Ont., superintendent of water works; Harold W. Horne, Collinsville, Conn., division engineer for the Board of Water Commissioners of Hartford; Frank E. Howard, Hartford, Conn., president of Board of Water Commissioners of Hartford; Louis Treal, Lewiston, Me., superintendent Lewiston Water Works; Edwin T. McDowell, Middletown, Conn., superintendent Middletown Water Works; James H. Reynolds, Lowell, Mass., laboratory assistant and chief filter attendant, Lowell Boulevard Purification Plant; Arthur F. Shuey, Tampa, Fla., superintendent water works. — 8.

Associate — Henry N. Schramm, Philadelphia, Pa., contractor and water-works equipment; A. G. Lemoine, Montreal, P. Q., automatic sprinklers. — 2.

On motion of Mr. Lewis M. Bancroft, the Secretary was directed to cast one ballot in favor of the applicants, and, he having done so, they were declared elected members of the Association.

On motion of Mr. Robert J. Thomas, it was voted that the President appoint a nominating committee of five to name officers for the year 1918. The President subsequently appointed as members of the committee R. C. P. Coggeshall, George A. Stacy, William T. Sedgwick, Frank E. Hall, F. F. Forbes.

Adjourned.

Evening Session.

At the ball room of the Hartford Club a reception was tendered to the members of the Association and their guests by the Hartford Chamber of Commerce. Mr. H. Wales Dixon, Superintendent of Recreation, Park Commission, gave a description of the Hartford park system, illustrated by lantern slides. The lecture dealt particularly with the facilities for recreation afforded in the Hartford parks to both old and young. Dancing was enjoyed during the later hours. Refreshments were served.

MORNING SESSION, WEDNESDAY, SEPTEMBER 12, 1917.

Vice-President Carleton E. Davis in the chair.

Mr. George A. Johnson, consulting engineer, New York City, read a paper entitled "Rapid Sand Filtration." Mr. R. S. Weston, consulting engineer, Boston, read a paper entitled "Mechanical Filter Bottoms and Strainer Systems."

These papers were discussed by Messrs. L. M. Hastings, R. E. Wise, Harold C. Stevens, William J. Willson, H. F. Dunham, Elbert E. Lockridge, and J. S. Dunwoody.

Mr. John W. Gaitenby, superintendent of filtration, Evansville, Ill., read a paper entitled "The Care and Operation of Rapid Sand Filters." The paper was discussed by Mr. Harold C. Stevens.

President Saville announced that Mr. F. L. Cady, of Providence, who was to have given a paper at this session entitled "Methods of Operation and Results Obtained with Slow Sand Filters," was unable to be present but that his paper had been received and would be read at a later session of the convention.

MR. W. C. HAWLEY. We were very kindly entertained last evening by the Hartford Chamber of Commerce, and it is proper for us to express our appreciation. I move, therefore, that the Secretary of the Association be instructed to address a communication to the Hartford Chamber of Commerce expressing the appreciation of this Association of the courtesies of the Chamber of Commerce, and expressing also our thanks.

The motion was duly seconded and carried unanimously.

AWARD OF BRACKETT MEDAL.

VICE-PRESIDENT DAVIS. Before we adjourn, I should like to call upon Mr. Baker to make an announcement of the award of the Dexter Brackett Memorial Medal.

MR. M. N. BAKER. *Mr. Chairman and Members of the Association and Guests,* — I regret that Mr. FitzGerald, the chairman of the committee, is not present, — all the more so because it would have been especially fitting for him to make this announcement in view of his long-time association with Mr. Brackett. You will remember that a year or so ago a committee appointed

for the purpose of collecting a fund for the Dexter Brackett Memorial reported that such a fund had been collected, and recommended that a medal be awarded annually for the most meritorious paper that had been presented during the past year. This recommendation was approved and the basis for the award was fixed so that the award would be based on the consideration of the papers that had been published in the JOURNAL through the previous year. The award would, therefore, be for the best paper published in the JOURNAL in 1916. It is a great pleasure to announce — and it seems particularly fitting that it should have turned out to be such a happy coincidence — that the committee has unanimously decided that the most meritorious paper was that of your present President, Mr. Saville, entitled "Some Water-Works Experiences in Hartford, Conn.," which appeared in the JOURNAL for June, 1916. [*Great applause.*]

MR. CALEB MILLS SAVILLE. I do not think any remarks are necessary on that, except to say that I was very greatly surprised and very greatly pleased, and rather affected in a way. The Dexter Brackett in memory of whom the medal is given was the engineer of the distribution department in Boston during all the time I was there, — a ten-year period. Three other men — Mr. William E. Foss, now chief engineer of the Metropolitan Board of Supply; Mr. John L. Howard, the assistant chief engineer of the same board, and Mr. Alfred D. Flinn, the deputy chief engineer of the New York Water Supply — and myself as the fourth, were Mr. Brackett's principal assistants in laying out and constructing the distribution works on the Metropolitan System. Any good work that any of us four men have done since that time is due in large measure to our contact with Mr. Brackett, a man of the most sterling character, a man who was known — I don't need to tell the older members of this Association anything about him at all; but it is with the greatest appreciation that I receive this honor from the hands of the New England Water Works Association. [*Applause.*]

VICE-PRESIDENT DAVIS. I would like to say that the award has been approved by the Executive Committee and the medal will be presented at the November meeting.

Adjourned.

Afternoon Session.

President Saville in the chair.

The Secretary read the following list of applicants for membership, approved by the Executive Committee:

Edwin L. Burnap, Norwich, Conn., superintendent Water Department; Theodore N. Kapoustine, Petrograd, Russia, special envoy from the mayor of Petrograd to study water supply conditions in the United States. — 2.

On motion of Mr. Lewis M. Bancroft, the Secretary was instructed to cast the ballot of the Association in favor of the applicants named, and he having done so they were declared to be elected members of the Association.

Mr. Delos F. Wilcox, deputy commissioner Department of Water Supply, Gas, and Electricity, New York City, read a paper entitled "The Regulation of Private Water Companies in New York City." Mr. Hiram A. Miller and Mr. H. F. Dunham took part in the discussion.

Mr. Bertram Brewer, city engineer and superintendent of sewers and water works, Waltham, Mass., read a paper entitled "Water Rates Revision in Waltham, Mass."

Mr. Fred D. Berry read a paper entitled "Some Experiences with a Trenching Machine," written by Mr. George W. Batchelder, water commissioner, Worcester, Mass.

Mr. H. W. Hosford, water commissioner of Northampton, Mass., read a paper entitled "Water-Works Shop Construction." The paper was illustrated by stereopticon views.

Mr. A. E. Martin, who was to have read a paper at this session, entitled "Water-Works Shop Construction," explained that he had been unable to obtain slides to illustrate his lecture but that he hoped to be ready to give it at either the November or December meeting. He extended an invitation to the members of the Association to visit their shop in Springfield.

Adjourned.

Evening Session.

President Saville announced that Capt. Edward Canfield, Jr., U.S.A., who was expected to read a paper at this session, entitled

"The Organization for Building the United States Army Cantonment at Ayer, Mass.," was unable to be present.

Mr. H. R. Turner, superintendent of water works, Windsor, Conn., read a paper entitled "Some Operating Problems of a Small Works Department." The paper was discussed by Messrs. Frank L. Fuller, Frank E. Merrill, P. J. Conlon, and George A. Stacy.

Mr. William Haine of the Newlands Sanitary Laboratory read a paper entitled "The Control of Microscopic Organisms in Water Supply." Messrs. Wm. A. McKenzie, Frank L. Fuller, S. H. McKenzie, P. J. Conlon, W. C. Hawley, Harold K. Barrows, Walter H. Richards, and Homer R. Turner took part in the discussion.

Mr. Fred D. Berry read a paper entitled "Experiences with the Universal Cast-Iron Pipe," written by Mr. John H. Walsh, superintendent of water works, East Hartford, Conn. Messrs. Wm. J. Willson, S. H. McKenzie, Alfred D. Flinn, and others took part in the discussion.

Adjourned.

Morning Session, Thursday, September 13, 1917.

This session was given over to the reading of a number of papers on Hartford's water-works system, by members of the engineering staff, as follows:

"Past and Present Supply," by W. E. Johnson, division engineer; "The Distribution System," by Frank Brainard, assistant engineer; "The Engineering Work on the New Supply," by H. W. Horne, division engineer; "Features in the Design of the Spillway at Richards' Corner Dam," by R. E. Wise, designing engineer; "Construction of Masonry Dam on Nepaug River," by H. W. Griswold, assistant engineer; and "Grouting of Dam Foundations," by J. E. Garratt, office engineer.

Discussion regarding the above papers was participated in by Chester R. McFarland, L. M. Hastings, H. F. Dunham, Homer R. Turner, Frank L. Fuller, President Saville, Harold K. Barrows, and Hiram A. Miller.

Adjourned.

Afternoon Session.

The Secretary read the following list of applicants for membership, approved by the Executive Committee:

Stephen Barden, West Springfield, Mass., for four years foreman in West Springfield; James H. Martin, West Springfield, Mass., foreman West Springfield Water Works.

On motion of Mr. Lewis M. Bancroft, the Secretary was instructed to cast the ballot of the Association in favor of the applicants named, and he having done so they were declared duly elected members of the Association.

Mr. J. L. Jackson, member of the Advisory Council of the Department of Health for the State of Connecticut, read a paper entitled "The Pollution of Streams in Connecticut." The paper was illustrated by steropticon views.

President Saville read a paper, illustrated by stereopticon views, entitled "Some Methods and Result of Filtration at Providence Water Works," written by Mr. Frank L. Cady, bacteriologist Providence Water Department, Providence, R. I.

Mr. S. E. Killam, superintendent pipe lines and reservoirs, Metropolitan Water Works, Boston, Mass., read a paper entitled "The Results of the Use of Meters in Metropolitan Water District, Boston." The paper was illustrated by stereopticon views. Messrs. Frank L. Fuller, W. A. McKenzie, F. H. McKenzie, Frank E. Merrill, President Saville, E. S. Cole, W. C. Hawley, Wm. J. Willson, and H. F. Dunham took part in the discussion.

Adjourned.

Evening Session.

President Saville. The first business will be the presentation of the report of the Committee on the Consumption of Water, — Mr. Edward S. Cole, of New York.

Mr. Edward S. Cole. *Mr. President and Gentlemen of the Association,* — As a preface, I might say that the work of this committee has been an attempt to segregate the uses of water so that the reported figures of per capita consumption for various cities might be compared more fairly and legitimately. For many years we have had only the total per capita use of water available. It was only on this basis that we have had to compare

one city's performance with another. And it was in order to produce a standard which would be a more reasonable basis of comparison that an effort was made through committee work to segregate the uses, and based upon meter readings. This committee has its final report to make in that connection.

(Mr. Cole then read the report of the Joint Committee on Water Consumption, New England Water Works Association, 1917.)

On motion of Mr. Frank L. Fuller, duly seconded, the report of the committee was accepted and adopted.

WAR-TIME CONSTRUCTION OF PUBLIC WORKS.

PRESIDENT SAVILLE. I am going to ask Mr. Richards to say a few words on municipal improvement, municipal work, and its relation to conditions at the present time.

MR. WALTER H. RICHARDS. *Mr. President and Gentlemen,* — What I have to say is a very few words. It won't take long to deliver my message, but it appears to me to be quite an important one. That is, what is the position of this Association in the matter? In a recent editorial in a paper devoted to advertising construction work and tools, the endeavor is made to prove that it is desirable to proceed with municipal construction work regardless of abnormal costs and abnormal conditions; indeed, the existence of these conditions is denied. These conditions are well known to any member of this Association who has undertaken construction work during the past year, whether by contract or by day labor, so that it is only necessary to state them briefly.

A large proportion of the day labor of this country is done by aliens or near aliens, a large portion of whom have now left this country to fight the battles of their own countries. Naturally they are the most efficient ones who have gone. Thus, while the cost of labor, due to scarcity, has advanced about 40 per cent., the efficiency has declined until the actual value of labor has been reduced at least 50 per cent., and this condition is likely to be exaggerated by the demand for men for our own armies.

The materials and tools which are required for construction have increased from two to three times in cost over that of years ago. It is, then, safe to say that the cost of any new construction has doubled in two years and is now double the normal or real value.

Whether construction at this time is paid for at once or by bonds or securities to be paid by posterity, the investment is twice its normal value. Would any careful business man make an investment without knowing that the future receipts would warrant the expenditure? It would seem that all new work except that immediately demanded for the preservation of life and health should be deferred until normal conditions are restored, for economic reasons.

But there is another reason: This country is at war, — your country, my country, is in jeopardy. Every dollar, every bit of energy, all the skill and efficiency should be devoted to saving it from destruction, and until that is accomplished nothing else matters. If a camp needs a water supply, build it and charge it up to profit and loss; but do not build anything that can be deferred until the future.

Many of the members of this Association are too old to carry a gun. Some of us could not tote a fifty-pound pack a half a mile, but, in the words of a distinguished member of this Association, "If we can't fight the Huns, we can hold the fort." [*Applause.*]

Mr. Henry R. Buck. This seems to me a most excellent idea, and one which the Association would do well to second at this time on economic grounds alone. We know that the cities can do the most good by furnishing work to the unemployed when there is a large number of unemployed. Here in Hartford, during the panic of 1893, work was found, that did not need to be done, to keep people busy, and economists tell us that we may expect another period of depression after the war. On that economic ground alone it seems to me worth while to defer every bit of unnecessary construction during these abnormal times. But the patriotic reason is, of course, so much stronger that that should take precedence over any mere economic reason. I understand that in England new construction of all sorts is absolutely forbidden. New residences are forbidden to be built except where absolutely necessary. It may come to that point in this country. Where we engineers can do so, I think we might very properly postpone any new projects.

President Saville. Did you put it in the form of a motion?

Mr. Richards. No, I did not. I move that it is the sense

of this Association that any public work, except that necessary for life and health, be deferred until conditions change.

The motion was duly seconded.

Mr. A. Prescott Folwell. I agree with what Mr. Richards said, and I should like to supplement it with a little idea of my own — a little additional idea. We want to be careful in judging what we mean by work which is immediately necessary. No one knows how long this war is going to last, — whether it is going to last six weeks or six years; but the probability is that for a short time after the discontinuance of the war, materials will still remain high, because there will be an unusual demand for them. As to the labor, that is, of course, another matter. But let us assume that the war will last for one year longer. During that time, within the next six months possibly, the United States will call for an additional number of men to join the army. That will mean that labor will become still more scarce. The price of material will not fall in the mean time; everything will rise. Consequently, it seems to me when we are trying to judge of what is immediately necessary, which we should endeavor to put through, we should consider as immediate anything which may be needed within the next year at least, — possibly two years, but let us say one year. Any work which is going to be needed within the next year, it seems to me, for economic and patriotic reasons both, should be put through as soon as possible because six months from now we will probably find both labor and material more scarce than they are at present.

The motion was unanimously carried.

Mr. George A. Stacy. Mr. President, I think at this time it is well to give the Association an opportunity to express its gratitude to the city of Hartford and its citizens for the courtesy that has been showered upon us, the hearty welcome we have received here, so that it may go upon the record. The weather has been magnificent, and that is typical of the conventions which we have held here. And I suppose that is due to the prayers and good-will of the citizens of Hartford, for which we are very thankful. And in order to put it in some kind of form and to put on record the feelings of the New England Water Works Association for the privilege of holding this convention here, the reception and the

courtesies which have been tendered us, I move that a vote of thanks be given to his Honor the Mayor; to the Hon. Charles Hopkins Clark, the editor of the Hartford *Courant;* to the Hon. Charles E. Gross, of the firm of Gross, Hyde & Shipman; to Mr. Frank G. Macomber, President of the Hartford Chamber of Commerce; and to those ladies who have so nobly and so well entertained our better halves and kept them satisfied, entertained, and happy, of whom Mrs. Frank G. Macomber is the chairman, assisted by a very able corps of ladies of the city of Hartford. We go away from here with new thoughts, with new ideas, and much to think of in the future. In the closing of this convention, as it is coming to a close, it is fitting that we should express this. Mr. Chairman, I move that a hearty vote of thanks be extended to these people I have mentioned, and many others I can't call to mind, for the courtesies, the hearty welcome, and the many kindnesses they have extended to us while we have been in this splendid city.

The motion was seconded.

MR. STACY. Excuse me; I made a serious blunder. I have not included the all-inclusive, — the Board of Water Commissioners of the City of Hartford, for which we have the deepest respect.

The motion was unanimously carried by a rising vote.

PRESIDENT SAVILLE. Before proceeding to the regular reports of the committees, or beginning with the regular reports, perhaps I will call on Mr. Woodburn for the report of his Committee on Exhibits of the associated members during this convention.

MR. WM. WOODBURN. I am sorry to say that on account of a number of little matters that came up late this afternoon we have not been able to get our report in shape, but I will have it ready so that it will be presented to you at the November meeting.

PRESIDENT SAVILLE. I think we are now ready to proceed with the regular reports of committees. Mr. Hawley, is your committee ready to report?

MR. W. C. HAWLEY. (Committee on Revenue from Fire Service.) We had a meeting on Monday of four of the members of the committee, but unfortunately none of those representing the insurance interests were there. I think that there is no serious difference between the water-works men on the committee and

those who represent the insurance interests, and I hope that we shall be able to present a report which shall be satisfactory and which will agree in principle, at any rate, with the reports of the American Water Works Association and the National Fire Protection Association.

In this connection I want to call the attention of the members of the convention very briefly to the Portland water decision. There are two or three things in that decision which are very interesting and which I think are going to be very helpful in the solution of the problem.

On motion of Mr. S. E. Killam, the report of progress of the committee was accepted, and the committee continued.

On motion of Mr. S. E. Killam the courtesy of the floor was extended to non-members during the discussion of topical matters.

There was a general discussion on the subject of water pipes for mains and services, participated in by Mr. Barker, of the Lock Joint Pipe Company; Mr. S. H. McKenzie, Mr. James E. Flinn, Mr. Henry R. Buck, Mr. F. N. Speller, and Mr. Carstein, of New York.

Adjourned.

FRIDAY, SEPTEMBER 14, 1917.

The day was devoted to an excursion to the sources of supply of the Hartford Water Works, by invitation of the Hartford Water Board.

EXECUTIVE COMMITTEE.

Meeting of the New England Water Works Association at Unity Hall, Hartford, Conn., at 1 o'clock P.M., Tuesday, September 11, 1917.

Present: President Caleb M. Saville, and members Carleton E. Davis, Samuel E. Killam, Frank J. Gifford, A. R. Hathaway, William S. Johnson, and Willard Kent.

Eight applications for active and two for associate membership were received and unanimously recommended therefor, viz.,

For Active: Louis Treal, superintendent water works, Lewiston, Me.; C. B. Crowell, general manager, Brattleboro Water Works Company, Brattleboro, Vt.; James H. Reynolds, laboratory assistant Lowell Boulevard Purification Plant, Lowell, Mass.; Edwin T. McDowell, superintendent water works, Middletown, Conn.; Frank E. Howard, president Board of Water Commissioners, Hartford, Conn.; Harold W. Horne, Collinsville, Conn.; Arthur F. Shuey, superintendent water works, Tampa, Fla.; Alexander Milne, engineer and superintendent water works, St. Catharines, Ont.

For Associate: Chris D. Schramm & Son, Philadelphia, Pa., and A. G. Lemoine, Montreal, Canada.

The following report of the Committee on Award of the Dexter Brackett Memorial Medal for the year 1916 was presented:

Report of the Committee to Recommend Award of the Dexter Brackett Medal.

The undersigned, a committee appointed by the New England Water Works Association to award the Brackett Medal for 1916, respectfully present the following report:

The principal condition governing the award of the Brackett Medal is as follows: "The medal shall be awarded for the paper which is judged to be most meritorious, bearing in mind its applicability to general water-works problems."

Bearing in mind the above condition, we recommend the award of the medal

to Caleb Mills Saville, for the paper entitled "Some Water-Works Experiences in Hartford, Connecticut."

DESMOND FITZGERALD, *Chairman*,
M. N. BAKER,
A. E. MARTIN,
Committee.

JULY 23, 1917.

And in accordance with their recommendation, the award was by unanimous vote made to Caleb Mills Saville, of Hartford, Conn.

Adjourned.

Attest:

WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at Unity Hall, Hartford, Conn., at 7.30 P.M., Thursday, September 13, 1917.

Present: President Caleb Mills Saville, and members Samuel E. Killam, Percy R. Sanders, William S. Johnson, Lewis M. Bancroft, and Willard Kent.

Four applications for membership were received and by unanimous vote recommended therefor, viz., Edwin L. Burnap, superintendent water works, Norwich, Conn.; Theodore N. Kapoustine, district engineer, Municipal Water-Works Department, Petrograd, Russia; Stephen Barden, foreman water works, West Springfield, Mass.; James H. Martin, foreman water works, West Springfield, Mass.

The Committee of Arrangements report the conditions under which the Manufacturers Association contributed to the expenses of the present convention as follows:

1. That none of their members, list of which is enclosed herewith, be requested for any contribution towards the entertainment fund;

2. That the Chairman of Exhibit Committee should be selected from among their members;

3. That the additional $5 charged Associate members for all representatives attending the convention in excess of one shall

be turned over to the Chairman of the Exhibit Committee to defray exhibit expense;

4. That the expenses of the Exhibit Committee will be distributed among the exhibitors in proportion to the square feet of space occupied by their exhibits;

whereupon it was voted: That the action of the Committee of Arrangements in relation to the present convention be approved without recommendation for future action.

Adjourned.

Attest:

WILLARD KENT, *Secretary.*

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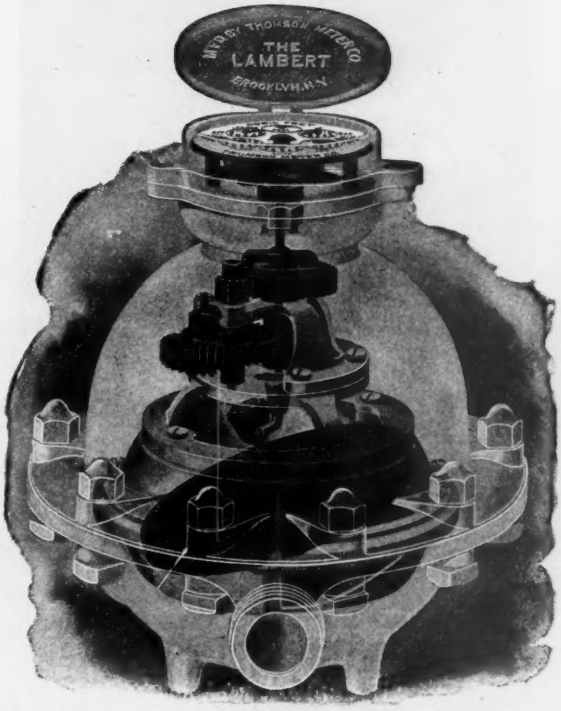

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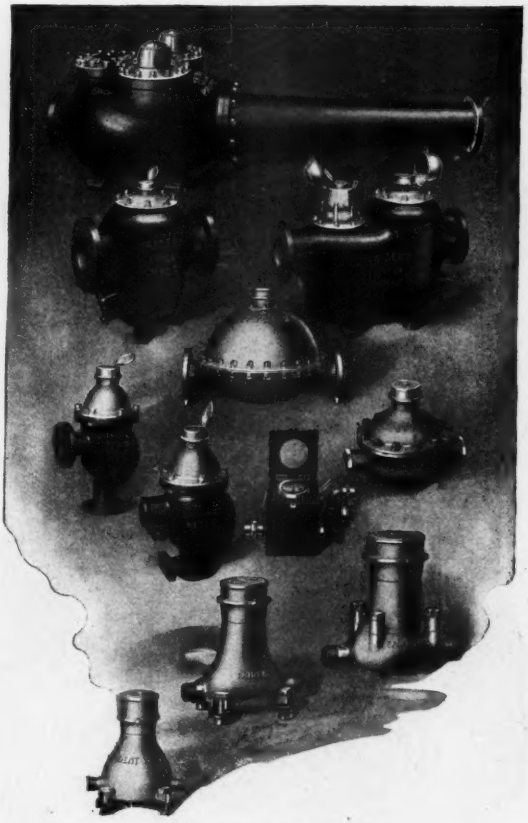

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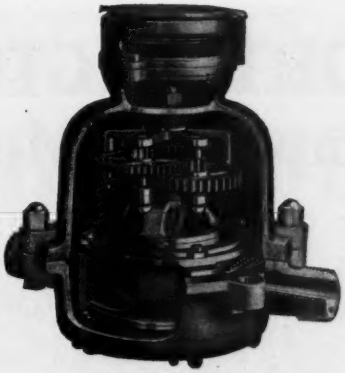

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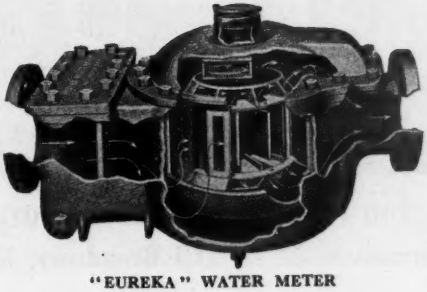

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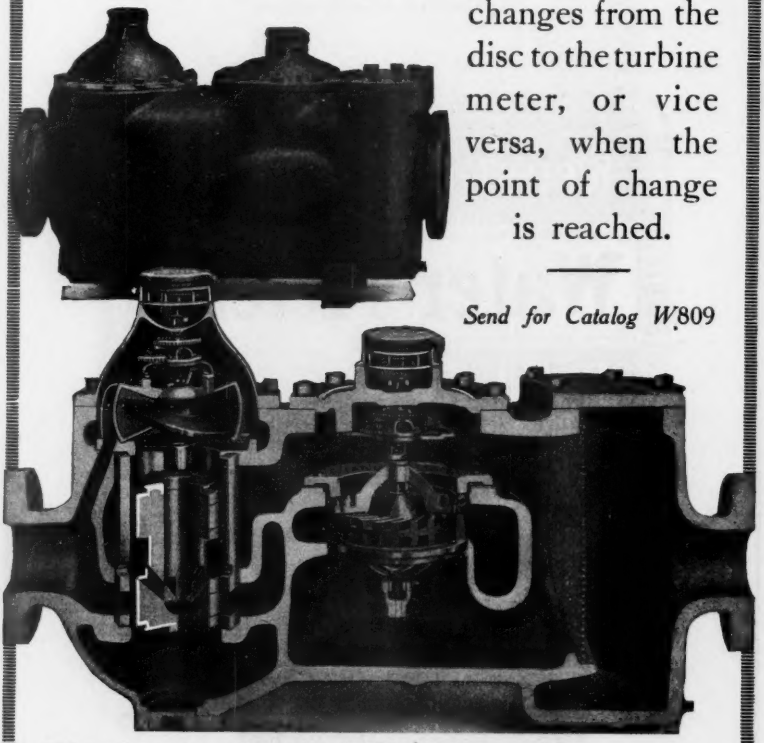

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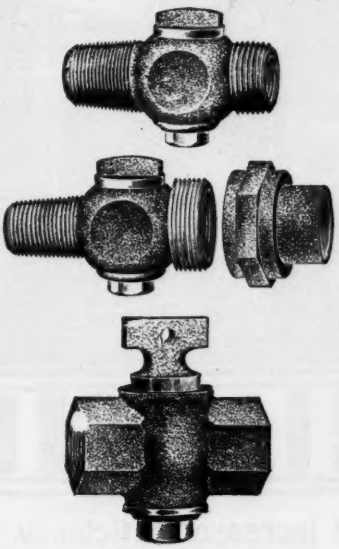

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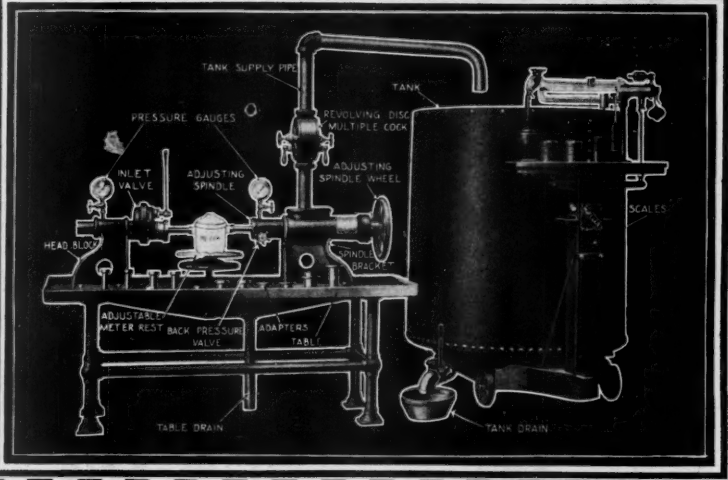

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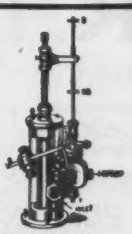

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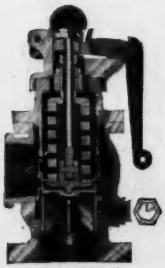

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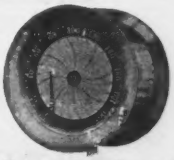

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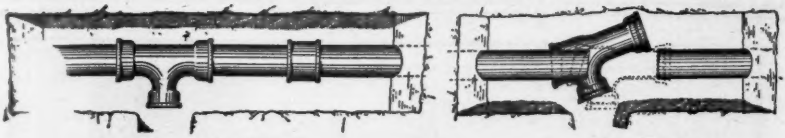

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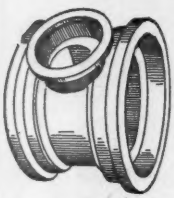

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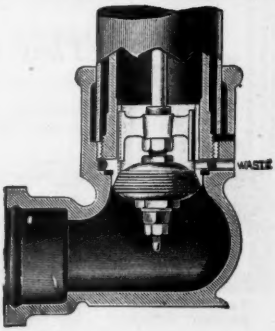

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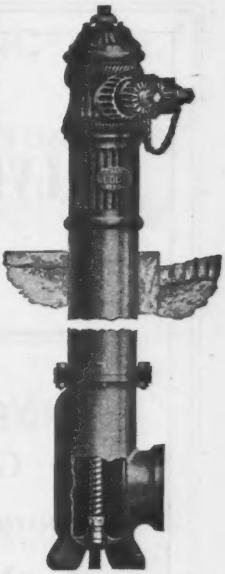

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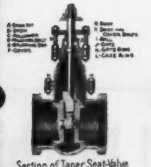
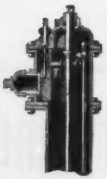
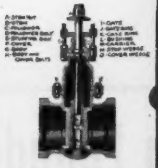


Section of Taper Seat-Valve.



Hydrant with Independent Nozzle Cut-off.



Section of Parallel Seat-Valve.

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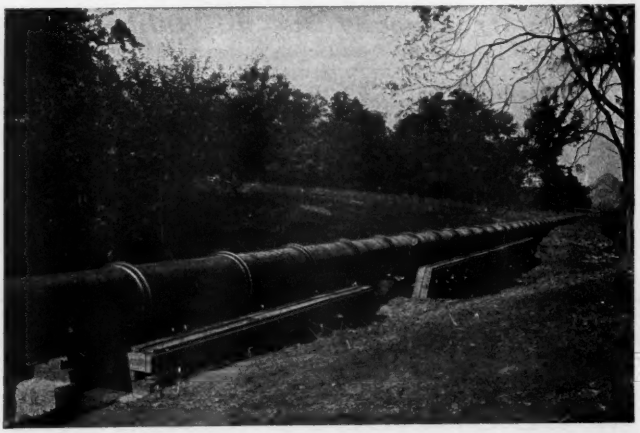

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New England Water Works Association,

ORGANIZED JUNE 12, 1882.

APPLICATION FOR MEMBERSHIP.

I, the undersigned, residing at.....

..... *being desirous of admission into the New England Water Works Association, hereby make application for* .....

(resident, non-resident or associate)

.....*membership.*

I am.....*years of age, and I have been engaged in the following named work:*

.....

.....

.....

I will conform to the requirements of membership if elected.

Signed,.....

Address,.....

Dated,.....*191*

Resident members are those residing in New England; all others are non-resident.
Entrance fee is $5.00 for resident and $3.00 for non-resident members.
Annual dues are $3.00 for both resident and non-resident members.